NATURAL HISTORY,

GENERAL AND PARTICULAR,

BY THE

COUNT DE BUFFON.

VOL. I.

THEORY OF THE EARTH.

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GENERAL AND PARTICULAR,

BY THE

COUNT DE BUFFON,

ILLUSTRATED WITH ABOVE SIX HUNDRED COPPER PLATES.

THE

HISTORY OF MAN AND QUADRUPEDS

TRANSLATED, WITH NOTES AND OBSERVATIONS,

BY WILLIAM SMELLIE,

MEMBER OF THE ANTIQUARIAN AND ROYAL SOCIETIES OF EDINBURGH.

A NEW EDITION,

CAREFULLY CORRECTED AND CONSIDERABLY ENLARGED, BY MANY ADDITIONAL ARTICLES, NOTES, AND PLATES,

AND

SOME ACCOUNT OF THE LIFE OF M. DE BUFFON

BY WILLIAM WOOD, F. L. S.

IN TWENTY VOLUMES

VOL. I.

LONDON:

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TO THE

COUNT DE BUFFON,

&c. &c. &c.

SIR,

YOU did me honour by permitting me to address to you my Translation of your illustrious work; and I am proud to exercise the privilege you so politely conferred upon me. The important information it contains, and the eloquence of its composition, joined to the ingenuity, taste, and erudition, with which it abounds, induced me to think that a version of it into the English language, by diffusing the knowledge of Nature, would increase the number of her admirers. The task, it must be acknowledged, was arduous; but your approbation and encouragement, by redoubling my vigour, diminished the difficulty of the labour.

It was with the liveliest pleasure that I received your communications respecting the valuable performances you have already published, and concerning those great undertakings which now engage your attention. I failed not to announce to your friends in this country the advantages which Science and Literature have yet to expect from you; and I need hardly observe, that their wishes and my own for the accomplishment of your purposes, are in proportion to the greatness of your talents.

The success which the Translation has met with, I impute to the celebrity of your name, and to the high value of the original.

I have the honour to be, with the most entire respect,

SIR,

Your most obedient, and

Most humble servant,

WILLIAM SMELLIE.

EDINBURGH,
May 10, 1781.

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ERRATA.

Page 220, line 3, *for* "Genes," *read* Genoa.
8, *for* "Paterne near Boulonge," *read* Paterno near Bologna.
9, *for* "Pouille," *read* La Puglia.
271, 20, *for* "furnace," *read* surface.

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PREFACE,

BY THE TRANSLATOR.

NATURAL History is the most extensive, and perhaps the most instructive and entertaining of all the sciences. It is the chief source from which human knowledge is derived. To recommend the study of it from motives of utility, were to affront the understanding of mankind. Its importance, accordingly, in the arts of life, and in storing the mind with just ideas of external objects, as well as of their relations to the human race, was early perceived by all nations in their progress from rudeness to refinement.

But, notwithstanding the great advantages to be derived from the knowledge of Nature, Aristotle is the only ancient writer on ZOOLOGY who merits attention. Instead of retailing fictions, or facts founded upon ignorance and credulity, he investi-

gated the relations and differences which connect and distinguish the various tribes of animals. What had been only a chaos of *detached, uncertain, and often* fabulous, narrations and descriptions, he reduced into a scientific form, with a success so amazing, that, to this hour, no systematic view of animated beings has been attempted, the principles of which have not been adopted from Aristotle's History of Animals. His analogies and distinctions are taken not only from the instruments of motion, the teeth, the eyes, the heart, and other external and internal organs of the body, to which the attention of our modern methodists has been chiefly confined, but from magnitude, figure, manners, faculties, and dispositions of mind. He attempted not to arrange and define every known species. This labour he left to men of less genius and more patience. His work consists entirely of philosophical dissertations on the general structure, manners, and dispositions of animals; and his particular facts are always employed to support the principles which he is endeavouring to establish.

Pliny and Ælian, though they had the

illustrious example of Aristotle before them, produced nothing but crude collections, without discovering much taste, judgment, or knowledge of the subject.

From this period, till the voluminous Gesner and Aldrovandus appeared, the knowledge of Nature, like other branches of literature, was involved in the general gloom of ignorance and superstition. It was the object of these authors to amass every thing that had been said of animals by poets, shepherds, grammarians, philosophers, physicians, and old women. Their prolixity, of course, is insufferable. Their labours, however, may be regarded as rude quarries, from which some valuable materials may be dug; but the expense of removing the rubbish will, perhaps, overbalance their intrinsic value.

In the same class, with little exception, may be ranked, Wotton, Belon, Rondeletius, Salvianus, Johnson, and a multitude of similar writers. They all transcribed, and sometimes abridged, the labours of their predecessors; but they uniformly lost sight of philosophy and science.

This race of phlegmatic writers was suc-

ceeded by our celebrated countrymen Mr. Ray and Mr. Willoughby, who were admirers of Nature, and lamented the slovenly dress in which she had been formerly *exhibited. They knew the value of her treasures, and wished to show them in their native brilliancy. They rejected dubious* and fictitious relations. They added, from observation and experiment, many new facts: they arranged animals under proper classes and subdivisions: they described with accuracy and precision: they pointed out the importance of the science, and recommended the study of it by the solidity and clearness of their views, and by the brevity and perspicuity of their compositions. This taste continued some time, and produced the Works of Reaumur, Trembley, Buffon, and similar publications.

From beginnings so prosperous, much was to be expected. But the excellency of method was no sooner recognised than the philosophy of the science was nearly extinguished by a profusion of new terms and arrangements. The justly celebrated Linnæus, by persevering industry, joined to

the utility of his technical dictionary*, unfortunately turned the attention of most naturalists, though contrary to the learned author's design, from the great views of Nature to the humble ambition of system-making. It is needless to specify examples. Every philosopher must have observed, with regret, that inundation of methodical distributions which have successively appeared during the course of these last thirty or forty years. Since Linnæus's works were published, the attention of Naturalists has been principally occupied with criticising former arrangements, and fabricating new ones. The philosophy of the science has, of course, been almost totally neglected. Natural history has been exhibited in its most forbidding aspect, which has limited the study of it to a few, and these often not of the most brilliant talents; for it has been remarked, that the parade of learning, resulting from technical phrases and definitions, allure some men to become what is called *great naturalists*, whose chief knowledge of Nature

* Systema Naturæ, which, with regard to quadrupeds, can be considered in no other light.

is the knack of being able to name, with facility, a great number of her productions.

This propensity for *multiplying methodical* distributions, and disputing about their respective merits, has brought much obloquy on the science of Nature. Men of sense perceive the folly of discussions concerning the local situation of an animal in a book. They consider the authors as learned triflers; and, what is worse, they are apt to regard a subject, which affords no better entertainment or information, as barren and unprofitable. To no other source can we ascribe the following sentiments, so frequently expressed by men of no inconsiderable talents: "That natural historians have seldom discovered extensive views; that they confine their chief attention to the mere technical part of the science; that they rarely take notice of manners and instincts, or the causes and œconomy of animal action; and that they never pursue these great and useful objects with a degree of taste and philosophical accuracy, proportioned to the importance of the subject." These strictures are common: I wish that they had no foundation in truth.

In natural history, two ends only can be attained by system. Both of them are useful; but they are extremely different in their kinds. System may be employed either to facilitate the distinction of objects, or to ascertain their relations in the scale of being.

The first species of system, it is obvious, must consist entirely of a series of external or internal characters. It is of little moment, whether the objects ranked under particular ORDERS be mutually connected; because, if we may judge from the many laborious, but abortive, attempts which have been made, Nature seems not to have expressed such connexions in characters recognisable by our senses. A system so limited in its principles and design, can never assume any other form than that of a technical index or dictionary. If the general and particular characters be so marked, that a student, after learning the divisions and language of the author, can investigate the proper names of the objects presented to him, this system is perfect; because its sole and primary intention is fulfilled.

Were every naturalist of the same senti-

ments with regard to this point, many incumbrances, which now load the science, *would be removed; the tyro would not be disgusted* and retarded by an infinity of synonyms; natural history would acquire a more simple and *intelligible form; and* the number of its votaries *would* soon be augmented.

The second species of system is more elevated and sublime. But, as it includes the whole philosophy of Nature, it requires a depth of judgment, a superiority of genius, an extent of knowledge, which are seldom united in the same person. Natural objects are wonderfully diversified in their structure, œconomy, and faculties. But, in these, as well as in many other circumstances, they are no less wonderfully connected. Here, then, are foundations for constructing the system of Nature. To mark the distinctions, to investigate the relations, to ascertain the great chain that unites the numerous tribes which people and adorn the universe, would demand talents superior, perhaps, to those of humanity. We ought not, however, to despair. *Hardly any bounds can be set to the combined force of different minds acting suc-*

cessively upon the same subject. Something has already been done. More may in time appear: Nature, in some future period, may happily unite philosophy and Natural History, a phænomenon which has hitherto been but partially exhibited.

Among those authors, whether ancient or modern, who have contributed to unfold the philosophy of Natural History, the count de Buffon holds the most distinguished rank. This learned and eloquent writer has introduced into his subjects a greater variety of disquisition, and given more comprehensive views of Nature, than any preceding or contemporary historian. His facts are, in general, collected with judgment and fidelity; and his reasonings and inferences are not only bold and ingenious, but adorned with all the beauties of expression, and all the charms of novelty. They every where lead to reflections which are momentous and interesting. They expand the mind, and banish prejudices. They create an elevation of thought, and cherish an ardour of inquiry. They open many great and delightful prospects of the œconomy of Nature, of the alterations and accidents to which she is liable, of the

causes of her improvement or degeneration, and of the general relations that connect the whole, and give rise to all the diversities which characterise and constitute particular orders of existence.

The original work, of which I have attempted a translation, was undertaken and carried into execution under the munificent encouragement of a great monarch. The design was to compose a history which should record not only every phænomenon in the universe that was already known, but to examine, describe, and delineate from the life, all the animals which could be procured by royal influence. A plan so extensive required the joint operation of, at least, two persons; the one to compose the historical part, the other to dissect and minutely describe every animal, both native and foreign, that should be obtained. The literary character and philosophic talents of the count de Buffon pointed him out for the execution of the first department; and the acuteness and anatomical skill of M. Daubenton recommended him for that of the second.

Three volumes of this great work were given to the public in the year 1749. These

volumes exhibited such displays of learning, taste, genius, and eloquence, as procured to the author uncommon admiration, and excited a strong and general desire for the completion of his plan; which, however, from various causes, was not accomplished till the year 1767.

The count de Buffon, in the year 1776, favoured the world with a supplementary volume to his history of quadrupeds, which, beside an ingenious dissertation *on Mules*, contains the history and figures of several new animals, and valuable additions to most of those described in the original publication.

It would be improper to enter more minutely into the history or contents of this magnificent work. Such is the fertility of the author's genius, and such his ardour for philosophic inquiry, that, when treating of the most common animals, he often astonishes his reader with the profoundness of his remarks, and the beauty of his analogical discussions.

But, though the publication was a great acquisition to literature; yet the high price of sixteen guineas, which was an unavoidable consequence of its splendour, and

of the prodigious number of its elegant engravings, confined its utility to men of opulence. Sensible of this inconvenience, the count de Buffon, a few years ago, published an edition in 12*mo;* and, to bring it within the reach of common purchasers, he excluded from it the long and minute anatomical dissections and mensurations.

After this short sketch of the count de Buffon's History of Nature, it may seem strange that no decent translation of it has hitherto appeared in the English language. To such an undertaking, the great expense of the engravings was one solid objection. Another arose from the vast variety of learning employed by the author. When to these are added the exuberance of his fancy, the eloquence and force of his diction, the delicacy and acuteness of his disquisitions, we should rather wonder how any man could reconcile himself to a task so laborious, and which required the union of such diversified talents.

* * * * *

This translation comprehends what is contained in the original fifteen volumes

in quarto, together with the supplementary volume to the history of quadrupeds, except the description of the king's cabinet, the dry and uninteresting anatomical dissections and mensurations, which can be of little use but to professed anatomists, and have been properly omitted by the author in the last Paris edition. The method of studying Natural History; the reprehension of methodical distributions; and the mode of describing animals, are likewise omitted. The chief intention of these discourses is to ridicule the authors of systematic arrangements, and particularly the late ingenuous and indefatigable sir Charles Linnæus, whose zeal and labours in promoting the investigation of natural objects merit the highest applause. There is a stronger reason for this omission: the same remarks and arguments are, perhaps, too frequently repeated in the history of particular animals.

To render this English version more valuable, the translator has added short distinctive descriptions to each species of quadrupeds. For these he has been indebted to the labours of the learned and ingenious Mr. Pennant. Beside these useful addi-

tions, the synonyms, and the generic and specific characters given by Linnæus, Klein, Brisson, and other naturalists, are subjoined to the description of each species.

Where the author commits mistakes, or where he recommends practices, regarding the management of particular animals, which differ from those observed in this country, the translator has taken the liberty of animadverting upon such passages in notes: but he has seldom taken any notice of peculiar theories or doctrines. These must rest upon the facts and arguments employed by the author. It was not the intention of the translator to write a commentary upon his original.

The great variety of subjects discussed by the count de Buffon, has already been mentioned. It is almost unnecessary to remark, that every subject demands a peculiar style. A bare enumeration of facts, or descriptions of the dimensions, figure, and colour of animals, admit of no other ornament than that of perspicuity. Topics of philosophy and argument require a higher and more figurative expression: and addresses to the passions, and the finer feelings of men, give full scope to the exer-

cise of genius and of taste. Of these different species of writing, the examples are numerous in the works of the count de Buffon. The translator has endeavoured to follow the original, as far as his abilities would permit. The degree of success he has attained must be submitted to the impartial determination of the public. He shall only say, that his apprehensions, though he is conscious of no voluntary negligence, are much greater than his hopes.

*** In the dimensions of animals, the translator has retained the French measures. The differences between the foot or inch of England and France are so inconsiderable, when applied to individual animals, that he thought it unnecessary to reduce them to the precise English standard, especially as the dimensions are English in the descriptions added in the notes.

SOME

ACCOUNT

OF THE

LIFE OF M. DE BUFFON,

BY THE EDITOR.

GEORGE Louis le Clerc, count de Buffon, the son of a counsellor of the parliament of Dijon, was born Sept. 7, 1707, at Montbard, in Burgundy. He was educated to the profession of the law, but his inclination for scientific pursuits, which showed itself at an early age, diverted his attention into another channel, and disappointed the wishes of his father. He was first attracted by astronomy, which

he pursued with all the ardour of youthful expectation; and, to facilitate his favourite study, applied himself strictly to geometry, and made Euclid his constant companion.

At twenty, he travelled into Italy, but he had then acquired such an inclination for the pursuit which afterwards engrossed all his attention, that the works of art were neglected for those of nature; fields and woods had more charms for him than palaces and pictures; and he was more inclined to the study of the brute creation, than the contemplation of learning, policy, or manners. He concluded his travels with a journey to England, and, at the age of twenty-five, returned to Paris, and spent the remainder of his life either in that city, or on his estate at Montbard.

In 1728, he succeeded to his mother's fortune, which was sufficiently ample to

place him in a state of affluence and independence, and to clear his literary path of those obstructions, which genius, unaided by wealth, can seldom remove.

In 1739, on the death of M. Dufay*, he was appointed superintendant of the Royal Garden and Cabinet; a situation which he held during his life, and for which he was admirably calculated. It

* When Dufay was upon his death-bed, some misunderstanding, which had previously existed between him and Buffon, was kindly removed by Hellot, a member of the academy, and the friend of both. He succeeded in advising Dufay to send a recommendatory letter to the minister, which contributed greatly to turn the scale in favour of Buffon; who had then to acquire that reputation which he atferwards enjoyed. Duhamel, who was at that time employed, with great credit to himself, on several important works in natural history, was said to have had a superior title to the situation; but he was at the same time appointed inspector of the marine; and Maurepas, the minister, thought that the duty of two such important places, was more than one man could well discharge.

was during the time he enjoyed this appointment, that so many marks of distinction were paid to his merit. His name became universally known, and his taste for *natural history* universally acknowledged. Objects relative to his favourite pursuit were sent him from all parts, and cases directed to the count de Buffon, when taken at sea, were respected even by pirates, and forwarded, unopened, to Paris.

He was now noticed by persons of the first distinction; nobility, princes, and even emperors, honoured him with their presence, and flattered him by their regard. He had a grateful recollection of the preference shown him by the late empress of Russia; her correspondence gratified his vanity, which was increased by her desiring his bust, to place in her palace.

Whilst he was thus distinguished, a prince of Austria visited the Royal Garden,

and was presented by Buffon with a superb copy of his works, which his highness, from an unintentional forgetfulness, left behind him. When the emperor, some time after, came to Paris, he hastened to repair the neglect: "I come," says he to the count, "to take from you those books, which my brother so unfortunately forgot."

At another time, prince Henry of Prussia, after having dined with the philosopher at Montbard, heard him read his history of the swan: when Buffon concluded, the prince expressed his satisfaction, and, on his return to Berlin, sent him a beautiful breakfast-set of porcelain, on which was painted the swan in all the situations and attitudes described in his history.

With such marks of favour and attention, from persons of the highest rank in society, it would be somewhat surprising to

find him deficient in one of the striking characteristics of his nation. Buffon was vain, but his vanity was so far excusable, since it was founded on a conscious superiority of talents, and raised by the repeated and unqualified praises of his friends.

He studied at Montbard, in a pavilion about a furlong from the house, called the tower of St. Louis. It stood at the end of the garden, and was accommodated only with a wooden desk and an arm chair. Within this was another sanctuary, called, by prince Henry of Prussia, "the cradle of natural history:" here he composed his works, and on this retreat no one was suffered to intrude.

He was indefatigable in his application, was extremely fond of study, and yet, in his early days, felt the inconveniences of indolence. He said to the chevalier Aude,

"I was a great lover of my bed in my youth. My poor Joseph" (a servant who lived with him more than sixty years) "assisted me greatly to conquer that propensity. I promised him a crown every time he roused me at six. The next morning he did not fail to do his duty, but I repulsed him; he came the morning after, and I threatened to turn him out of the room. Thou hast gained nothing Joseph, and I have lost my time, said I to him at noon; you know not how to manage me; think only of my promise, and do not listen to my threats. The next morning he fulfilled my wishes, *by forcing me to rise in spite of my ill humour*; and every succeeding day he was indemnified for my cross temper when I awoke, by my thanks and a crown, which he received an hour after: indeed, I owe to my poor Joseph ten or twelve volumes of my works."

The chevalier Aude speaks of Buffon as an excellent and affectionate husband. He married Mademoiselle de St. Berlin, a young lady of good family, agreeable manners, and great beauty, but of no fortune. While she lived, he did all in *his power to make her happy; and ever after her death, retained a tender regard* for her memory.

In 1771, his sovereign conferred upon him a flattering mark of distinction, by erecting his estate *into a comté. Thus by* investing Buffon with a title, to which he was by no means indifferent, he gratified a man to whom literary fame was every thing, and who well knew that the popularity which he had gained by his writings, would suffer no diminution from the acquirement of rank.

Much of the latter part of Buffon's life was spent in pain: he was afflicted with

one of the most excruciating disorders to which our frame is liable; and suffered all that torture from the stone, which may be felt, but cannot be described. He is said to have borne his malady with great fortitude and patience, and to have lingered on till the 81st year of his age. He died on the 16th of April, 1788, and his body, after being embalmed, and presented first at St. Medard's church, was conveyed to Montbard, and interred (by his previous desire) *in the same vault with his wife.*

In his last moments, he was attended by an affectionate and respectable female friend, Madam Neckar, who seldom quitted him during the continuance of his complaint. Some days before his death, he refused all kinds of nourishment. "It is not," says he to the people about him, "that I am an untractable patient; but what can your attentions do for me? they are

useless; I feel that I am dying." He expressed some impatience for the arrival of the priest, and said, "They leave me to die without the sacrament." On receiving the last assistance which it was in the power of the church to give him, he publicly renewed the profession of his faith; and, desiring his son to approach, said to him, "Never quit the path of honour and of virtue, it is the only way to be happy:" soon after this, he pressed the hands of his friends, and, for the last time, closed his eyes.

Every proper respect was paid to his body, and his funeral was attended by most of the academicians, and persons of rank, and literary note; besides a crowd of at least twenty thousand people, who lined the streets to see him pass. Thus the attention and deference which the superiority of his talents exacted during life, were

continued to his remains after his decease; and therefore the following severe remark, in his observations on old age and death, though it is confirmed in too many instances, can in nowise be applied to him. "The greatest part, even of the most savage people, pay more attention than we to their departed friends. What we esteem as a ceremony only, they regard as a primary duty: they respect their dead, they clothe them; they speak to them; they recite their exploits; they praise their virtues: but we, who pretend to superior sensibility, fly from our dead, and inhumanly abandon them; we have neither the courage nor the inclination to speak of them; we even avoid such objects or situations as might recal the idea of them: we are therefore either more indifferent or weaker than savages*."

* Vol. ii. p. 228.

The stones taken from his body after death, weighed two ounces six drams; and it was the opinion of the faculty, that lithotomy might have been performed without danger, if he would have submitted to the operation.

He left an only son, a major in the regiment of Angoumois, who, in the year 1793, when only thirty years of age, fell a victim to the revolutionary tribunal, during the sanguinary reign of Robespierre.

Buffon, had a noble, manly figure, and a calm, placid, and very intelligent countenance. He was vain of his person, and so attentive to his external appearance, that he would employ a hair-dresser two or three times a day, and appear, on Sundays, before the peasantry at Montbard, in laced clothes. He was extremely tenacious of his title, and, notwithstanding his philosophy, was very jealous of any

infringement on the rights of his new county. He was of a lively, cheerful disposition, and a great talker; but in his turn, he would listen to what others had to say, and politely attend to frivolous, as well as learned discourse.

Of his domestic habits, we have the following account. He generally rose before six, dressed himself for the day, dictated his letters, and regulated his family concerns. About six, he retired to the tower of St. Louis at the end of the garden, and studied till nine, when his breakfast was brought him, which consisted of two glasses of wine and a slice of bread. After breakfast, he wrote for two hours; and then returned to the house. At dinner, he indulged in all the gaieties and trifles that occurred at table, and sometimes in freedom of conversation, which, before ladies, exceeded the rules of delicacy and

decorum. When dinner was finished, he paid little attention either to his family or guests; generally slept about an hour in his room; then took a solitary walk, and concluded the day by conversing with his friends, or examining papers that were submitted to his judgment: at nine he went to bed. The greatest portion of his life was spent in this regular manner: one day was the history of nearly fifty years; and our surprise at the quantity he composed will be lessened, when we consider the time he set apart for the purpose.

He was passionately fond of music, and was often moved to tears by the harmony of fine sounds. Some years before he died, he said to the curate at Montbard, "Do you know why I so seldom attend at mass? it is because I cannot assist at that awful ceremony without shedding tears."

An apology, in such a case, is always weak, but by no means singular: we often hear of inconveniences in a church, which are not noticed elsewhere; and the mind is very ready at inventing an excuse for the omission of a duty, which we feel it wrong to neglect, without having any inclinationto perform.

It is said that he was lax and unguarded in his intercourse with women; that he used expressions before females which were neither fit for them to hear nor him to utter; and that he was unfaithful to his wife. It is not for me to attempt a refutation of these charges, the general tenor of his writings give but too much reason to suspect their truth; yet as the biographers of his own country, while they freely criticise his vanity, are silent with respect to his vice, it will be but common charity to hope that his accusers were misinformed.

It is to be lamented that a bright genius and a cultivated understanding, does not exempt its possessor from the common failings of humanity; and that education, however it may tend to control the passions, is often insufficient to subdue them. Buffon was extremely envious of his great cotemporary, and seldom mentions Linnæus, or his system, without expressing contempt. The naturalist of Sweden, on his part, never deigns to quote Buffon, although he must have been well aware of the ample elucidations his works would have afforded him.

Buffon wrote with difficulty; he would sometimes spend a whole morning in turning a single period; and was very particular in forming the style of his writings. He often repeated, that style was every thing; that an author could not consider it too carefully, and that the poets have no style, because they are confined to the

rules of metre, which enslaves them. Such an assertion would hardly be expected from a man of letters; but it seems that, from some unsuccessful attempts in his youth, he took a dislike to poetry, and therefore ventured an opinion on what he did not understand. He considered style as being formed of two things, invention and expression. "Invention," says Buffon, "depends on patience; contemplate your subject at leisure, and it will gradually unfold, till you at length feel it, like an electric spark, strike upon the brain, and communicate to the heart." He describes this as the favourable moment, when what, at other times, may be called the toil of authorship, becomes a pleasure: when the luxury of genius is felt in its fullest extent, and the mind is as readily disposed to suggest, as the pen is to execute. "At such times," says

Buffon, "I have spent twelve or fourteen hours at my desk with great delight."

It is reasonable to suppose, that the full enjoyment of the comforts of this life, and the respect and homage, which his learning and fortune procured him from the world, contributed not a little to increase his attachment to literature. He was placed in a state of affluence far beyond the ordinary reach of pecuniary embarrassment, and therefore knew not the distress which attends a dependence for support on the will of others. His literary path was strewed with flowers. He never felt the want of fortune, or of friends; and was consequently spared the misery which genius too often suffers from indigence, and the neglect which is so generally produced by poverty.

It is said of him, that when he was recommending the perusal of capital works

in every department of taste and science, he added, with singular self-confidence, "Capital works are scarce. I know but five great geniuses, Newton, Bacon, Leibnitz, Montesquieu, and *myself*." He would recite whole pages of his writings to his friends; and, notwithstanding his vanity, was ever ready to listen to their objections, to argue points of difference with them, and to yield to their suggestions, when he was convinced of their judgment.

His earnest desire of literary fame, made him carefully and repeatedly revise his works before he published them; and, rather than hazard his reputation by posthumous publications, he destroyed every paper which he considered either as useless or unfinished. Those who are inclined to judge him severely, say, that he often uses language which is too lofty

for his subject; and that he indulges in a strain of eloquence, where plain writing only is required. The Abbé Trublet has made the following remark on this position: "Whatever is intended to be pronounced," says the Abbé, "ought to be eloquent; that which is meant to be read, may also be eloquent, but it should not be too much so; what appears eloquent in an oration, seems like bombast in a subject which does not admit of eloquence: we may describe a battle between spiders and flies with warmth; but, in such a case, we have no right to assume the tone of Homer, when he paints the wrath of Achilles!"

The first works in which Buffon engaged were translations from the English, of Hales's Vegetable Statics, and Newton's Fluxions: the first, published in 1735; and the last, in 1740. These were followed

by his Theory of the Earth, which made its appearance in 1744, and was afterwards incorporated with his Natural History. His great and celebrated work, the Natural History of Man and Quadrupeds, commenced in 1749, and was completed in 1767, in fifteen volumes, 4to. Seven supplementary volumes were afterwards added. The anatomical part of this great labour was entirely the work of his coadjutor, M. Daubenton.

A long and severe indisposition, with which Buffon was afflicted, after the completion of his Quadrupeds, interrupted his literary labours, and prevented the two first volumes of his History of Birds from appearing till the year 1771. He was greatly indebted for the composition of these to Gueneau de Montbeillard, whose style and manner were so like his own, that the public could scarcely distinguish the one from the other. In the four succeed-

ing volumes, in which he was assisted by the same person, the difference is immediately detected; the name of each writer being prefixed to his respective articles. There are in all nine volumes, and in the three last he received most essential assistance from the Abbé Bexon, whose knowledge of the subject enabled him to communicate many useful observations. The work was completed in 1783. In the same year, he produced the first volume of his History of Minerals, which was completed in 1788, in five volumes, 4to. To these works by Buffon, his friend and pupil, Lacepede, added the Oviparous Quadrupeds, Serpents, and Fishes. As a guide to those who may be disposed to consult Buffon in his own language, I have noticed the different Paris editions, from the earliest date to the present time*.

* Buffon, (G. L. Leclerc, comte de) Histoire

The labours of Buffon have now been known to the public for more than half

Naturelle, générale et particulière. Paris, 1749, et suiv. 45 tom. 4to.

The volumes which compose this edition are thus divided:

The Theory of the Earth, with the History of Man and Quadrupeds, 15; Supplements, 7; Birds, 9; Minerals, 5; Oviparous Quadrupeds, and Serpents, 2; Fishes, 5; Cetaceous Animals, 1; Atlas, 1.

The copies in which the errata are placed at the end of each volume contain the best impressions of the plates; the errata being omitted in the second and subsequent editions.

Œuvres complete de Buffon, &c. Paris, 1774, et suiv. 36 tom. 4to.

The anatomical part in this edition is omitted.

Histoire Naturelle, générale et particulière, de Buffon, &c. Paris, 1752, et suiv. 89 tom. 12mo.

The same, without the anatomical part, in 71 volumes.

The same, published in 1785—91, in 54 volumes, with coloured figures. This edition wants the oviparous quadrupeds, serpents, and fishes, and is very indifferently executed.

a century. They have long ago passed the critical ordeal, and it is pretty gene-

Histoire Naturelle, générale et particulière mise dans un nouvel Ordre, par M. Lacepede. Paris, 1799. 74 tom. 18mo. 830 planches.

There are copies of this edition on fine paper, with coloured plates.

Histoire Naturelle, &c., de Buffon, Cours complet, mise en Ordre par M. M. Castel et Patrin. Paris, 1799—1802. 80 tom. 18mo. figures plain and coloured.

Besides the works of Buffon, this pretty edition contains the natural history of fishes, reptiles, insects, shells, plants, and minerals.

Histoire Naturelle, &c., de Buffon; rédigé par C. S. Sonnini. Paris, 1799, et suiv. 127 tom. 8vo. figures plain and coloured.

This is the latest and best edition of Buffon's works, in which all his supplements are properly incorporated, and many additions made by Sonnini. It is continued so as to form a complete course of natural history. The first 64 volumes contain the works of Buffon, the rest are in continuation.

Buffon et Montbeillard. Histoire Naturelle

rally acknowledged, that while they contain much to praise, they are by no means undeserving of reproach. The sentiments which they promulgate, that have any relation to religion, are extremely erroneous. The reader will soon perceive that Buffon is strongly attached to the system of materialism; that he is a decided enemy to the doctrine of final causes; and that he refers to unconscious nature, every operation that ought to be attributed to a designing and benevolent Deity. He never "looks through nature, up to nature's God," but perversely substitutes the effect for the cause, the emanation of the Divinity, for the Divinity itself.

des Oiseaux. Paris, 1771. 10 tom. fol. et 4to.

This splendid edition of the birds was printed in folio and quarto, and contains 1008 coloured plates, 35 of which represent insects.

Wherever his descriptions relate to sex, his grossness is offensive; and that which ought to be treated with all modesty of expression, is frequently displayed with a studied sensuality, that defeats the purpose it was intended to promote. The mind revolts at such glaring want of delicacy, and all desire of information is lost in feelings of disgust.

Independent of these blemishes, which are not to be defended, "no writer," as it has been justly observed, "has ever done so much to render natural history entertaining, or to elevate its rank among the objects on which the human intellect has been employed." The strongest proof that can be given of this assertion is; that, notwithstanding the objectionable parts, his works have been eagerly sought for in different countries, and translated into several languages. It may be also added,

that succeeding naturalists have almost universally availed themselves of his information, though frequently without acknowledgment.

To Buffon, therefore, cannot be refused the first rank among the writers on natural history. His labours afford ample proofs of the power of genius, when directed by taste, and his particular descriptions of animals often exhibit an elegance of style, which in no other work, of the kind, is to be met with. He had a mind well calculated for his task, and was indefatigable in his exertions to procure information. He spared no pains or expense to forward his undertaking, nor any labour to complete it. Inattention and idleness were equally unknown to him. He never wasted the day in making resolutions for the morrow; but, by constant and well regulated exertion, has left us a striking example of what may be

done by a proper division of our time, a due observance that no part of it passes unemployed, and a patient and steady perseverance in whatever we undertake.

Before I conclude this account of Buffon, it will probably be expected of me to say something on the alterations, the additions, and, what I may esteem, the improvements of the present edition. The editor of a book is generally considered as a sort of drudge, who, if he exerts himself to the utmost, may indeed escape censure, but can scarcely hope for praise. His duty is reckoned a dull one, and his notes are often entirely disregarded; or, what is worse, are condemned for increasing the volume of the book, by occupying a space that would have been better filled by the author. I have,

notwithstanding the little encouragement afforded to editors by the literary world, undertaken the present task, and have devoted my nights to its completion. Many works have been consulted, and many volumes attentively examined in its progress; and this, not in the calm and undisturbed enjoyment of my time, but subject to those professional interruptions, which originate in the diseases of our fellow-creatures, and therefore admit of no excuse.

The translation of the quadrupeds, by Smellie, in 1781, comprehends all that was at that time published by his author, and the supplements (as in the original copy) were left at the end of their respective articles. These have been incorporated in their proper places, as well as the whole of the ninth volume, relating to the theory of the earth. The Eng-

lish text has been very carefully compared with the original, and freely corrected, wherever it has appeared to want amendment. The numerous additions which the count de Buffon made to the history of quadrupeds, after Smellie's work was published, have been regularly translated, (except a useless dissertation on mule dogs,) and added to the present edition. These additions are accompanied by 110 extra plates, engraved for the purpose. Buffon was greatly averse to systematic order; his different animals are therefore left where he placed them, *except in a few instances*, especially among the smaller quadrupeds, as in the bats and squirrels; which are now placed in succession, to obviate the necessity of turning, so frequently, to different volumes, for the same kind of animals. The Linnæan generic and specific charac-

ters, to each genus, and article, have been regularly arranged; the references to different authors, carefully examined; and the particular countries which the animals inhabit, briefly noticed. A synopsis of such quadrupeds as have been discovered since the time of Buffon, is now added as an Appendix; and it may be proper to observe, that every alteration or addition which has been made to the work, except in the text, is distinguished by a *W.*, that no errors or imperfections of mine may be unjustly charged upon another person. In conclusion, I must offer my best thanks to Dr. Latham, of Rumsey, for the use of his excellent Index Ornithologicus, to which I am wholly indebted for the specifications of the Birds.

THE

HISTORY AND THEORY

OF THE

EARTH.

THE figure of the earth*, its motions, or the external relations which subsist between it and the other parts of the universe, belong not to our present inquiry. It is the internal structure of the globe, its form and manner of existence, which we here propose to examine. The general history of the earth ought to precede that of its productions. Details of particular facts, relating to the economy and manners of animals, or to the culture and vegetation of plants, are not, perhaps, so much the objects of natural history; as general deductions from the observations that have been made upon the different materials of which the earth itself is composed; as its heights, depths, and inequalities; the motions of the sea, the direction of moun-

* See subsequent proofs of the theory of the earth, art. i

tains, the situation of rocks and quarries, the rapidity and effects of currents in the ocean, &c. This is the history of Nature at large, and of her principal operations, by which every other inferior or less general effect is produced. The theory of these effects constitutes what may be called the primary science, upon which a precise knowledge of particular appearances, as well as of terrestrial substances, solely depends. This species of science may be considered as appertaining to physics; but, is not all physical knowledge, where system is excluded, a part of the history of Nature?

In subjects of an extensive kind, the relations of which it is difficult to trace, where some facts are but partially known, and others obscure, it is more easy to form a fanciful system, than to establish a rational theory. Thus the theory of the earth has never hitherto been treated but in a vague and hypothetical manner. I shall, therefore, exhibit a cursory view only of the notions of some authors who have written upon this subject.

The first hypothesis I shall mention is more conspicuous for its ingenuity than solidity. It is the production of an English astronomer*, who was an enthusiastic admirer of sir Isaac Newton's system of philosophy. Convinced that every possible event depends upon the motions and direction of the stars, he endeavours to prove, by means of mathematical calculations,

* Whiston. See the proofs, art. ii.

that all the changes this earth has undergone have been produced by the tail of a comet.

For another hypothesis, we are indebted to a heterodox divine *, whose brain was so fully impregnated with poetical illusions, that he imagined he had seen the universe created. After telling us the state of the earth when it first sprung from nothing, what changes have been introduced by the deluge, what the earth has been, and what it now is, he assumes the prophetic style, and predicts what will be its condition after the destruction of the human kind.

A third writer †, a man of more extensive observation than the two former, but equally crude and confused in his ideas, explains the principal appearances of the globe by the aid of an immense abyss in the bowels of the earth, which, in his estimation, is nothing but a thin crust, inclosing this vast ocean of fluid matter.

These hypotheses are all constructed on tottering foundations. The ideas they contain are indistinct, the facts are confounded, and the whole is a motley jumble of physics and fable. They, accordingly, have never been adopted but by men who embrace opinions without examination, and who, incapable of distinguishing the degrees of probability, are more deeply impressed with marvellous chimeras than with the genuine force of truth.

My ideas on this subject will be less extraor-

* Burnet. See proofs, art. iii.

† Woodward. See proofs, art. iv.

dinary, and may even appear unimportant, when compared with the grand systems of such hypothetical writers. But it should not be forgotten, that it is the business of an historian to describe, not to invent; that no gratuitous suppositions are to be admitted in subjects which depend upon fact and observation; and that, in historical compositions, the imagination cannot be *employed, except for the purpose of combining observations, of rendering facts more general, and of* forming a connected whole, which presents to the mind clear ideas and probable conjectures: I say, probable; for it is impossible to give demonstrative evidence on this subject. Demonstration is confined to the mathematical sciences. Our knowledge in physics and natural history depends entirely on experience, and is limited to the method of reasoning by induction.

With regard to the history of the earth, therefore, we shall begin with such facts as have been universally acknowledged in all ages, not omitting those additional truths which have fallen within our own observation.

The surface of this immense globe exhibits to our observation heights, depths, plains, seas, marshes, rivers, caverns, gulfs, volcanos; and, on a cursory view, we can discover, in the disposition of these objects, neither order nor regularity. If we penetrate into the bowels of the earth, we find metals, minerals, stones, bitumens, sands, earths, waters, and matter of every kind, seemingly placed by mere accident, and without any apparent design. Upon a nearer and more

attentive inspection, we discover sunk mountains *, caverns filled up, shattered rocks, whole countries swallowed up, new islands emerged from the ocean, heavy substances placed above light ones, hard bodies inclosed within soft bodies; in a word, we find matter in every form, dry and humid, warm and cold, solid and brittle, blended in a chaos of confusion, which can be compared to nothing but a heap of rubbish, or the ruins of a world.

These ruins, however, we inhabit with perfect security. The different generations of men, of animals, and of plants, succeed one another without interruption: the productions of the earth are sufficient for their sustenance; the motions of the sea, and the currents of the air, are regulated by fixed laws †; the returns of the seasons are uniform, and the rigours of winter invariably give place to the verdure of the spring. With regard to us, every thing has the appearance of order: the earth, formerly a chaos, is now a tranquil, an harmonious, a delightful habitation, where all is animated and governed by such amazing displays of power and intelligence, as fill us with admiration, and elevate our minds to the contemplation of the great Creator.

But let us not decide precipitantly concerning the irregularities on the surface of the earth, and the apparent disorder in its bowels: we shall

* See Senec. Quæst. lib. 6. cap. 21. Strab. Geog. lib. 1. Orosius, lib. 2. cap. 18. Plin. lib. 2. cap. 19. Hist. de l'Acad. des Sciences, année 1708, p. 23.

† See the proofs, art. xiv.

soon perceive the utility, and even the necessity of this arrangement. With a little attention, we shall perhaps discover an order of which we had no conception, and general relations that cannot be apprehended by a slight examination. Our knowledge, indeed, with regard to this subject, must always be limited. We are entirely unacquainted with many parts of the surface of this globe *, and have partial ideas only concerning the bottom of the ocean, which, in many places, has never been sounded. We can only penetrate the rind of the earth. The greatest caverns †, the deepest mines ‡, descend not above the eight thousandth part of its diameter. Our judgment is therefore confined to the upper stratum, or mere superficial part. We know, indeed, that, bulk for bulk, the earth is four times heavier than the sun; we likewise know the proportion its weight bears to that of the other planets. But still this estimation is only relative. We have no standard. Of the real weight of the materials we are so ignorant, that the internal part of the globe may be either a void space, or it may be composed of matter a thousand times heavier than gold. Neither is there any method of making farther discoveries on this subject. It is even with difficulty that rational conjectures can be formed ||.

We must therefore confine ourselves to an accurate examination and description of the surface

* See proofs, art. vi. † Phil. Trans. abridged, vol. ii. p. 323. ‡ Boyle's Works, vol. iii. p. 232.

|| See proofs, art. i.

of the earth, and of such inconsiderable depths as we have been able to penetrate. The first object which attracts attention, is that immense collection of waters with which the greatest part of the globe is covered. These waters occupy the lowest grounds; their surface is always level; and, notwithstanding their uniform tendency to equilibrium and rest, they are kept in perpetual agitation by a powerful agent *, which counteracts their natural tranquillity, which communicates to them a regular periodic motion, alternately elevating and depressing their waves, and which produces a concussion or vibration in the whole mass, even to the most profound depths. This motion of the waters is coëval with time, and will endure as long as the sun and moon, by which it is produced.

In examining the bottom of the sea, we perceive it to be equally irregular as the surface of the dry land †. We discover hills and valleys, plains and hollows, rocks and earths of every kind ‡: we discover, likewise, that islands are nothing but the summits of vast mountains, whose foundations are buried in the ocean ||; we find other mountains whose tops are nearly on a level with the surface of the water; and rapid currents which run contrary to the general movement §. These currents sometimes run

* See proofs, art. xii.

† Proofs, art. xiii.

‡ See M. Buache's chart of the depths of the ocean between Africa and America.

|| Varenii Geog. gen. p. 218.

§ Proofs, art. xiii.

in the same direction; at other times their motion is retrograde *; but they never exceed their natural limits, which seem to be as immutable as those which bound the efforts of land-rivers. On one hand, we meet with tempestuous regions, where the winds blow with irresistible fury, where the heavens and the ocean, equally convulsed, are mixed and confounded in the general shock; violent intestine motions, tumultuous swellings †, water spouts ‡, and strange agitations, produced by volcanos, whose mouths, though many fathoms below the surface, vomit forth torrents of fire, and push, even to the clouds, a thick vapour, composed of water, sulphur, and bitumen; and dreadful gulfs or whirlpools ||, which seem to attract vessels for no other purpose than to swallow them up. On the other hand, we discover vast regions of an opposite nature, always smooth and calm, but equally dangerous to the mariner §. Here the winds never exert their force; the nautical art is of no utility; the becalmed voyagers must remain immoveably fixed, till death relieve them from misery. To conclude, directing our eyes toward the southern or northern extremities of the globe, we discover huge masses of ice ¶, which, detaching themselves from the polar re-

* Varen. p. 140. and Voyages de Pirard, p. 137.

† Shaw's Travels. ‡ Proofs, art. xvi.

|| The Malestroom in the Norwegian Sea.

§ The calms and tornados in the Æthiopian Sea.

¶ Proofs, art. vi. and x.

gions, advance, like floating mountains, to the more temperate climates, where they dissolve and vanish from our view *.

Beside these grand objects, the ocean presents us with myriads of animated beings, almost infinite in variety: some, clothed in light scales, swim with amazing swiftness; others, loaded with thick shells, trail heavily along, leaving their traces in the sand: to others, Nature has given fins resembling wings, with which they support themselves in the air, and fly before their enemies to considerable distances. Lastly, the sea gives birth to other animals, which, totally deprived of motion, live and die immoveably fixed to the same rocks: all, however, find abundance of food in this fluid element. The bottom of the ocean, and the shelving sides of rocks, produce plentiful crops of plants of many different species; its soil is composed of sand, gravel, rocks, and shells; in some places, it is a fine clay, in others, a compact earth; and, in general, the bottom of the sea has an exact resemblance to the dry land which we inhabit.

Let us next take a view of the land: what prodigious differences take place in different climates! What a variety of soils! What inequalities in the surface! But, upon a more attentive observation, we shall perceive, that the great chains of mountains lie nearer the equator than the poles †; that, in the Old Continent, their direction is more from east to west than from

* See Buache's chart, 1739.

† Proofs, art. ix.

south to north; and that, on the contrary, in the New Continent, they extend more from north to south than from east to west. But, what is still more remarkable, the figure and direction of these mountains, which have a most irregular appearance *, correspond so wonderfully, that the *prominent* angles of one mountain are constantly opposite to the *concave* † angles of the neighbouring mountain ‡, and of equal dimensions, whether they be separated by an extensive plain or a small valley. I have farther remarked, that opposite hills are always nearly of the same height; and that mountains generally occupy the middle of continents, islands, and promontories, dividing them by their greatest lengths ||. I have likewise traced the courses of the principal rivers, and find that their direction is nearly perpendicular to the sea-coasts into which they empty themselves; and that, during the greatest part of their courses, they follow the direction of the mountains from which they derive their origin §. The sea-coasts are generally bordered with rocks of marble and other hard stones, or rather with earth and sand accumulated by the waters of the sea, or brought down and deposited by rivers. In opposite coasts, separated only by small arms of the sea, the different strata or beds of earth are of the same materials ¶. I find that volcanos never exist but in high

* Proofs, art. ix. xii.

† *Saliant* and *re-entering* angles; Muller's Fortification.

‡ Lettres Phil. de Bourguet, p. 181. || Varen. Geog. p. 69.

§ Proofs, art. x. ¶ Ibid. art. vii.

mountains*; that a great number of them are entirely extinguished; that some are connected with others by subterranean passages, and their eruptions not unfrequently happen at the same time †. There are similar communications between certain lakes and seas. Some rivers suddenly disappear ‡, and seem to precipitate themselves into the bowels of the earth. We likewise find certain mediterranean or inland seas, which constantly receive, from many and great rivers, prodigious quantities of water, without any augmentation of their bounds, probably discharging, by subterraneous passages, all these extraneous supplies. It is likewise easy to distinguish lands which have been long inhabited, from those new countries where the earth appears in a rude state, where the rivers are full of cataracts, where the land is either nearly overflowed with water or burnt up with drought, and where every place capable of producing trees is totally covered with wood.

Proceeding in our examination, we discover that the upper stratum of the earth is universally the same substance ||; that this substance, from which all animals and vegetables derive their growth and nourishment, is nothing but a composition of the decayed parts of animal and vegetable bodies, reduced into such small particles that their former organic state is not distinguishable. Penetrating a little deeper, we find the

* Proofs, art. xvi.
† Kircher Mund. subter in præf.
‡ Varen. Geog. p. 43.
|| Proofs, art. vii.

real earth, beds of sand, lime-stone, clay, shells, marble, gravel, chalk, &c. These beds are always parallel to each other*, and of the same thickness through their whole extent. In neighbouring hills, beds or strata of the same materials are uniformly found at the same levels, though the hills be separated by deep and large valleys. Strata of every kind, even of the most solid rocks, are uniformly divided by perpendicular fissures†. Shells, skeletons of fishes, marine plants, &c., are often found in the bowels of the earth, and on the tops of mountains‡, even at the greatest distances from the sea. These shells, fishes, and plants, are exactly similar to those which exist in the ocean. Petrified shells are to be met with, almost every where, in prodigious quantities: they are not only inclosed in rocks of marble and lime-stone, as well as in earths and clays, but are actually incorporated and filled with the very substances in which they are inclosed. In fine, I am convinced, by repeated observation, that marbles, lime-stones, chalks, marls, clays, sand, and almost all terrestrial substances, wherever situated, are full of shells and other spoils of the ocean ||.

Having enumerated these facts, let us try what conclusions can be drawn from them.

The changes which the earth has undergone during the last two or three thousand years are

* Proofs, art. vii. and Woodward, p. 41, &c.

† Ibid. art. viii. ‡ Id. ibid.

|| Steno, Woodward, Ray, Bourguet, Scheuchzer, Phil. Trans. Mem. de l'Acad. &c.

inconsiderable, when compared with the great revolutions which must have happened in those ages that immediately succeeded the creation. For, as terrestrial substances could only acquire solidity by the continued action of gravity, it is easy to demonstrate, that the surface of the earth was at first much softer than it is now; and, consequently, that the same causes, which at present produce but slight and almost imperceptible alterations during the course of many centuries, were then capable of producing very great revolutions in a few years. It appears, indeed, to be an incontrovertible fact, that the dry land which we now inhabit, and even the summits of the highest mountains, were formerly covered with the waters of the sea; for shells, and other marine bodies, are still found upon the very tops of mountains. It likewise appears, that the waters of the sea have remained for a long track of years upon the surface of the earth; because, in many places, such immense banks of shells have been discovered, that it is impossible so great a multitude of animals could exist at the same time. This circumstance seems likewise to prove, that, although the materials on the surface of the earth were then soft, and, of course, easily disunited, moved, and transported, by the waters; yet these transportations could not be suddenly effected. They must have been gradual and successive, as sea-bodies are sometimes found more than one thousand feet below the surface. Such a thickness of earth or of stone could not be accumulated in a short period.

Although it should be supposed, that, at the deluge, all the shells were transported from the bottom of the ocean, and deposited upon the dry land; yet, beside the difficulty of establishing this supposition, it is clear, that, as shells are found incorporated in marble and in the rocks of the highest mountains, we must likewise suppose, that all these marbles and rocks were formed at the same time, and at the very instant when the deluge took place; and that, before this grand revolution, there were neither mountains, nor marbles, nor rocks, nor clays, nor matter of any kind, similar to what we are now acquainted with, as they all, with few exceptions, contain shells, and other productions of the ocean. Besides, at the time of the universal deluge, the earth must have acquired a considerable degree of solidity, by the action of gravity for more than sixteen centuries. During the short time the deluge lasted, therefore, it is impossible that the waters should have overturned and dissolved the whole surface of the earth, to the greatest depths that mankind have been able to penetrate.

But, not to insist longer on this point, which shall afterwards be more fully canvassed, I shall confine myself to known and established facts. It is certain, that the waters of the sea have, at some period or other, remained for a succession of ages upon what we now know to be dry land; and, consequently, that the vast continents of Asia, Europe, Africa, and America, were then the bottom of an immense ocean, replete with every thing which the present ocean produces.

It is likewise certain, that the different strata of the earth are horizontal, and parallel to each other*. This parallel situation must, therefore, be owing to the operation of the waters, which have gradually accumulated the different materials, and given them the same position that water itself invariably assumes. The horizontal position of strata is almost universal: in plains, the strata are exactly horizontal. It is only in the mountains that they are inclined to the horizon; because they have originally been formed by sediments deposited upon an inclined base. Now, I maintain, that these strata must have been gradually formed, and that they are not the effect of any sudden revolution; because nothing is more frequent than strata composed of heavy materials placed above light ones, which never could have happened, if, according to some authors, the whole had been blended and dissolved by the deluge, and afterwards precipitated†. On this supposition, every thing should have had a different aspect from what now appears. The heaviest bodies should have descended first, and every stratum should have had a situation corresponding to its specific gravity. *In this case, we should not have seen solid rocks or metals placed above light sand, nor clay under coal.*

The beds of calcarious matters are not only horizontal in the plains, but likewise in all mountains which have not been disturbed by

* Proofs, art. vii. † Ibid. art. iv.

earthquakes or other accidental causes: and, when the strata are inclined, the whole mountain is likewise inclined, and has been forced into that position by a subterraneous explosion, or by the sinking of a part of the earth, which had served it as a basis. We may therefore conclude, in general, that all strata formed by the sediments of water are horizontal, like the water itself, except those which have been formed on an inclined base, as is the case with the most part of coal-mines.

The most external part of the earth, whether in plains or mountains, is solely composed of vegetable earth, which owes its origin to sediments of the air, of vapours, and of dews, and to the successive destruction of herbs, leaves, and other parts of decomposed plants. This first stratum every where follows the declivities and curvatures of the earth, and is more or less thick, according to particular local circumstances *. The vegetable stratum is commonly much thicker

* On the tops of some mountains, the surface is absolutely naked, and presents nothing to the view but pure rock, or granite, without any vegetation, except in the small fissures, where the wind has transported sand, and collected the particles of earth which float in the air. At some distance from the last branch of the Nile, there is a mountain composed of granite, of porphyry, and of jasper, which extends more than twenty leagues in length by perhaps an equal number in breadth. The surface of the summit of this enormous quarry, we are assured, is absolutely devoid of vegetables, and forms a vast desert, where neither quadrupeds, nor birds, nor even insects, can exist. But exceptions of this kind, which are particular and local, merit no consideration.

in valleys than on hills; and its formation is posterior to that of the primitive strata of the globe, the most ancient and most internal of which have been formed by fire, and the newest and most external have derived their origin from matters transported and deposited in the form of sediments by the motion of the waters. These, in general, are horizontal; and it is only by the action of particular causes that they sometimes appear inclined. The beds of calcarious stones are commonly horizontal, or slightly inclined; and, of all calcarious substances, the beds of chalk preserve their horizontal position most exactly. As chalk is only the dust of decayed calcarious bodies, it has been deposited by waters whose movements were tranquil, and their oscillations regular; whilst the matters which were only broken into large masses, have been transported by currents, and deposited by the removal of the waters; which is the reason why their strata are not so perfectly horizontal as those of chalk. The high coasts of Normandy are composed of horizontal strata of chalk so regularly perpendicular, that, at a distance, they have the appearance of fortified walls. Between the strata of chalk there are small beds of black flint, which give rise to the black veins in white marble.

Beside the calcarious shells, the strata of which are slightly inclined, and whose position has never been changed, there are many others which have been deranged by different accidents, and which are all much inclined. Of

these there are many examples in various parts of the Pyrennees, some of which are inclined forty-five, fifty, and even sixty degrees below the horizontal line. This circumstance seems to prove, that great changes have been produced in these mountains by the sinking of subterraneous caverns, which had formerly supported them.

Another circumstance demands our attention. No cause but the motion and sediments of water could possibly produce the regular position of the various strata of which the superficial part of this earth is composed. The highest mountains consist of parallel strata, as well as the lowest valleys. Of course, the formation of mountains cannot be imputed to the shocks of earthquakes, or to the eruptions of volcanos. Such small eminences as have been raised by volcanos or convulsions of the earth, instead of being composed of parallel strata, are mere masses of weighty materials, blended together in the utmost confusion *. But this parallel and horizontal position of strata must necessarily be the operation of a uniform and constant cause.

We are, therefore, authorized to conclude, from repeated and incontrovertible facts and observations, that the dry and habitable part of the earth has for a long time remained under the waters of the sea, and must have undergone the same changes which are at present going on

* Proofs, art. xvii.

at the bottom of the ocean. To discover what has formerly happened to the dry land, let us examine what passes in the bottom of the sea; and we shall soon be enabled to make some rational conclusions with regard to the external figure and internal constitution of the earth.

The ocean, from the creation of the solar system, has been constantly subject to a regular flux and reflux. These motions, which happen twice in twenty-four hours, are principally occasioned by the action of the moon, and are greater in the equatorial regions than in other climates. The earth likewise performs a rapid motion round its axis, and, consequently, has a centrifugal force, which is also greatest at the equator. This last circumstance, independent of actual observations, proves that the earth is not a perfect sphere, but that it must be more elevated under the equator than at the poles. From these two combined causes, the tides and the motion of the earth, it may be fairly concluded, that, although this globe had been originally a perfect sphere, its diurnal motion, and the ebbing and flowing of the tides, must necessarily, in a succession of time, have elevated the equatorial parts, by gradually carrying mud, earth, sand, shells, &c., from other climates, and depositing them at the equator *. On this supposition, the greatest inequalities on the surface of the earth ought to be, and, in fact, are found, in the neighbourhood of the equator. Besides, as the

* Proofs, art. xii.

alternate motion of the tides has been constant and regular since the existence of the world, is it not evident, that, at each tide, the water carries from one place to another a small quantity of matter, which falls to the bottom as a sediment, and forms those horizontal and parallel strata that every where appear? The motion of the waters, in the flux and reflux, being always horizontal, the matter transported by them must necessarily take the same parallel direction after it is deposited.

To this reasoning, it may be objected, that, as the flux is equal to, and regularly succeeded by, the reflux, the two motions will balance each other; *or, that the matter brought by the flux will be carried back by the reflux*; and, *consequently, that this cause of the formation of strata must be chimerical, as the bottom of the ocean* can never be affected by a uniform, alternate motion of the waters; far less could this motion change its original structure, by creating heights, and other inequalities.

But, in the first place, the alternate motion of the waters is by no means equal; for the sea has a continual motion from east to west: besides, the agitations occasioned by the winds produce great inequalities in the tides. It will likewise be acknowledged, that, by every motion in the sea, particles of earth, and other materials, must be carried from one place, and deposited in another; and that these collections of matter must assume the form of parallel and horizontal strata. Farther, a well known fact

will entirely obviate this objection. On all coasts, where the ebbing and flowing are discernible *, numberless materials are brought in by the flux, which are not carried back by the reflux. The sea gradually increases on some places, and recedes from others, narrowing its limits, by depositing earth, sand, shells, &c., which naturally take a horizontal position. These materials, when accumulated and elevated to a certain degree, gradually shut out the water, and remain for ever in the form of dry land.

But, to remove every doubt concerning this important point, let us examine more closely the practicability of a mountain's being formed at the bottom of the sea, by the motion and sediments of the water. On a high coast, which the sea washes with violence during the flow, some part of the earth must be carried off by every stroke of the waves. Even where the sea is bounded by rock, it is a known fact, that the stone is gradually wasted by the water †; and, consequently, that small particles are carried off by the retreat of every wave. Those particles of earth or stone are necessarily transported to some distance. Whenever the agitation of the water is abated, the particles are precipitated in the form of a sediment, and lay the foundation of a first stratum, which is either horizontal or inclined, according to the situation of the surface upon which they fall. This stratum will

* Proofs, art. xix. † See Shaw's Travels.

soon be succeeded by a similiar one, produced by the same cause; and thus a considerable quantity of matter will be gradually amassed, and disposed in parallel beds. In process of time, this gradually accumulating mass will become a mountain in the bottom of the sea, exactly resembling, both in external and internal structure, those mountains which we see on the dry land. If there happened to be shells in that part of the bottom of the sea where we have supposed the sediments to be deposited, they would be covered, filled, and incorporated with the deposited matter, and form a part of the general mass. These shells would be lodged in different parts of the mountains, corresponding to the times they were deposited. Those which lay at the bottom, before the first stratum was formed, would occupy the lowest station; and those which were afterwards deposited, would be found in the more elevated parts.

In the same manner, when the bottom of the sea, at particular places, is troubled by the agitation of the waters, earth, clay, shells, and other matter, must necessarily be removed from these parts, and deposited elsewhere. For we are assured by divers, that the bottom of the sea, at the greatest depths to which they descend *, is so strongly affected by the agitation of the water, that earth, clay, and shells, are removed to great distances. Transportations of this kind must, therefore, be constantly going on in every

* Boyle's Works, vol. iii. p. 232.

part of the ocean; and the matters transported, after subsiding, must uniformly raise eminences similar, in every respect, to the composition and structure of our mountains. Thus the motions produced by the flux and reflux, by winds and currents, must uniformly create inequalities in the bottom of the ocean.

Farther, we must not imagine that these matters cannot be carried to great distances, since we daily find grain, and other productions of the East and West Indies, arriving on our coasts *. These bodies are, indeed, specifically lighter than water; and the other substances are specifically heavier. Still, however, as they are reduced to an impalpable powder, they may be kept long suspended in the water, and, of course, transported to any distance.

It has been conceived, that the agitation produced by the winds and tides is only superficial, and affects not the bottom, especially when it is very deep. But it ought to be remembered, that, whatever be the depth, the whole mass is put in motion by the tides at the same time; and that, in a fluid globe, this motion would be communicated even to the centre. The power which occasions the flux and reflux is penetrating; it acts equally upon every particle of the mass. Hence the quantity of its force, at different depths, may be determined by calculation.

* Particularly on the coasts of Scotland and of Ireland. See Ray's Discourses.

Indeed, this point is so certain, that it admits not of dispute.

We cannot, therefore, hesitate in pronouncing, that the tides, the winds, and every other cause of motion in the sea, must produce heights and inequalities in its bottom; and that these eminences must uniformly be composed of regular strata, either horizontal or inclined. These heights will gradually augment; like the waves which formed them, they will mutually respect each other; and, if the extent of the base be great, in a series of years they will form a vast chain of mountains. Whenever eminences are formed, they interrupt the uniform motion of the waters, and produce new motions, known by the name of currents. Between two neighbouring heights in the bottom of the ocean, there must be a current *, which will follow their common direction, and, like a river, cut a channel, the angles of which will be alternately opposite through the whole extent of its course. These heights must continually increase; for, during the flow, the water will deposit its ordinary sediment upon their ridges, and the waters which are impelled by the current will force along, from great distances, quantities of matter, which will subside between the hills, and, at the same time, scoop out a valley with corresponding angles at their foundation. Now, by means of these different motions and sediments, the bot-

* Proofs, art. xiii.

tom of the ocean, though formerly smooth, must soon be furrowed, and interspersed with hills and chains of mountains, as we actually find it at present. The soft materials, of which the eminences were originally composed, would gradually harden by their own gravity. Such of them as consisted of sandy and crystalline particles, would produce those enormous masses of rock and flint in which we find crystals and other precious stones. Others, composed of stony particles mixed with shells, give rise to those beds of lime-stone and marble, in which vast quantities of sea shells are still found incorporated. Lastly, all our beds of marble and chalk have derived their origin from particles of shells mixed with a pure earth, collected and deposited at particular places in the bottom of the sea. All these substances are disposed in regular strata; they all contain heterogeneous matter and vast quantities of sea bodies, situated nearly in proportion to their specific gravities. The lighter shells are found in chalk; the heavier in clay and lime-stone. These shells are uniformly filled with the matter in which they are found, whether it be stone or earth. This is an incontestible proof, that they have been transported along with the matter that fills and surrounds them, and that this matter was then in the form of an impalpable powder. In a word, all those substances, the horizontal situation of which has arisen from the waters of the sea, invariably preserve their original position.

It may here be objected, that most hills, the

summits of which consist of solid rocks, or of marble, are founded upon small eminences, composed of less heavy materials, such as clay or light sand, the strata of which commonly extend over the neighbouring plains. If the above theory be just, what could bring about an arrangement so singular, so contrary to the laws of gravity? But this phænomenon admits of a natural and easy explication. The waters would operate first upon the upper stratum, either of coasts or the bottom of the sea: this upper stratum consists generally of clay or sand; and these light substances, being carried off and deposited previous to the more dense and solid, they would of course form small eminences, and become foundations for the more heavy particles to rest upon. After the light, superficial substances were removed, the harder and more ponderous would next be subjected to the attrition of the water, reduced to a fine powder, and carried off and deposited above the hillocks of sand or clay. These small stony particles would, in a succession of ages, form those solid rocks which we now find on the tops of hills and mountains. As particles of stone are heavier than sand or clay, it is probable that they were originally covered and pressed by superior strata of considerable depth; but that they now occupy the highest stations, because they were last transported by the waves.

To confirm this reasoning, let us investigate more minutely the situation of those materials which compose the superficial part of the globe,

the only part of which we have any adequate knowledge. The different strata of stones in quarries are almost all horizontal, or regularly inclined. Those founded upon hard clay, or other solid matter, are evidently horizontal, especially in plains. The disposition of quarries, where flint or brownish free-stone are found in detached portions, is indeed less regular. But even here the uniformity of nature is not interrupted; for the horizontal or regularly inclining position of the strata is apparent in granite and brown free-stone, wherever they exist in large connected masses. This position is universal, except in flint and brown free-stone in small detached portions; substances, the formation of which we shall demonstrate to have been posterior to those just now mentioned. The strata of granite, vitrifiable sand, clays, marbles, calcarious stones, chalk and marls, are always parallel or equally inclined. In these the original formation is easily discoverable; for the strata are exactly horizontal, and very thin, being placed above each other like the leaves of a book. Beds of sand, of soft and hard clay, of chalk, and of shells, are likewise either horizontal or uniformly inclined. Strata of every kind preserve the same thickness through their whole extent, which is often many leagues, and might, by proper observations, be traced still farther. In a word, the disposition of strata, as deep as mankind have hitherto penetrated, is the same.

Those beds of sand and gravel which are washed down from mountains, must, in some

measure, be excepted from the general rule. They are sometimes of a considerable extent in valleys, and are situated immediately under the soil or first stratum. In plains, they are level, like the more ancient and interior strata. But near the bottom, or upon the ridges of hills, they have an inclination corresponding to that of the ground upon which they have been deposited. As these beds of sand and gravel are formed by rivers and brooks, which, especially in the valleys, often change their channels, it is not surprising that such beds should be so frequent. A small rivulet is sufficient, in a course of time, to spread a bed of sand or gravel over a very large valley. In a champaign country, surrounded with hills, whose bases, as well as the upper stratum of the plain, consisted of a hard clay, I have often observed, that, above the origin of the brooks or rivers, the clay was situated immediately under the vegetable stratum; but, in the low grounds, there was a stratum of sand, about a foot thick, above the clay, and extending to a great distance from the banks of the rivers. The strata formed by rivers are not very ancient; they are easily distinguished by their frequent interruptions, and the inequality of their thickness. But the ancient strata uniformly preserve the same dimensions through their whole extent. Besides, these modern strata may be distinguished, with certainty, by the form of the stones and gravel they contain, which bear evident marks of having been rolled, smoothed, and rounded by the motion of water. The same ob-

servation may be made with regard to those beds of turf, and corrupted vegetables, which are found in marshy grounds, immediately below the soil: they have no claim to antiquity, but have derived their existence from successive accumulations of decayed trees, and other plants. The strata of slime, or mud, which occur in many places, are also recent productions formed by stagnating waters, or the inundations of rivers. They are not so exactly horizontal, nor so uniformly inclined, as the more ancient strata, produced by the regular motions of the sea. In strata formed by rivers, we meet with river, but seldom with sea shells; and the few which occur are broken, detached, and placed without order. But, in the ancient strata, there are no river shells; the sea shells are numerous, well preserved, and all placed in the same manner, having been transported and deposited at the same time, and by the same cause. From whence could this beautiful regularity proceed? Instead of regular strata, why do we not find the matters composing the earth huddled together without order? Why are not rocks marbles, clays, marls, &c., scattered promiscuously, or joined by irregular or vertical strata? Why are not heavy bodies uniformly found in a lower situation than light ones? It is easy to perceive, that this uniformity of nature, this species of organization, this union of different materials by parallel strata, without regard to their weights, could only proceed from a cause equally powerful and uniform as the motions

of the sea, produced by regular winds, by the tides, &c.

These causes act with superior force under the equator than in other climates; for there the tides are higher, and the winds more uniform. The most extensive chains of mountains are likewise in the neighbourhood of the equator. The mountains of Africa and Peru are the highest in the world, often extending through whole continents, and stretching to great distances under the waters of the ocean. The mountains of Europe and Asia, which extend from Spain to China, are not so elevated as those of Africa and South America. According to the relations of voyagers, the mountains of the north are but small hills, when compared with the mountains of the equatorial regions. Besides, in the northern seas, there are few islands; but, in the Torrid Zone, they are innumerable. Now, as islands are only the summits of mountains, it is apparent, that there are more inequalities on the surface of the earth near the equator, than in northerly climates.

Those prodigious chains of mountains which run from west to east in the Old Continent, and from north to south in the New, must have been formed by the general motion of the tides. But the origin of the less considerable mountains and hills must be ascribed to particular motions, occasioned by winds, currents, and other irregular agitations of the sea: their formation *may, indeed, be owing to a combination of all these motions, which are capable of infinite va-*

riations; for the winds, and the situation of different islands and coasts, constantly change the natural course of the tides, and oblige them to run in every possible direction. It is not, therefore, surprising to see considerable eminences which have no determined direction in their courses. But, for our present purpose, it is sufficient to have shown, that mountains have not been produced by earthquakes, or other accidental causes, but that they are effects equally resulting from the general laws of nature, as well as their peculiar structure, and the situation of the materials of which they are composed.

But how has it happened, that this earth, which we and our ancestors have inhabited for ages, which, from time immemorial, has been an immense continent, dry, compact, and removed from the reach of the water, should, if formerly the bottom of an ocean, be now exalted to such a height above the waters, and so completely separated from them? Since the waters remained so long upon the earth, why have they now deserted it? What accident, what cause, could introduce a change so great? Is it possible to conceive a cause possessed of power sufficient to operate such an amazing effect?

These are difficult questions. But, as the facts are incontrovertible, the precise manner in which they have happened may remain a secret, without prejudice to the conclusions that ought to be drawn from them. A little reflection, however, will furnish us at least with plau-

sible solutions*. We daily observe the sea gaining ground on certain coasts, and losing it on others. We know, that the ocean has a general and uniform motion from east to west; that it makes violent efforts against the rocks and the low grounds which encircle it; that there are whole provinces which human industry can hardly defend from the fury of the waves; and that there are instances of islands which have but lately emerged from the waters, and of regular inundations. History informs us of inundations and deluges of a more extensive nature. Should not all these circumstances convince us, that the surface of the earth has experienced very great revolutions, and that the sea may have actually given up possession of the greatest part of the ground which it formerly occupied? For example, let us suppose, that the Old and New worlds were formerly but one continent, and that, by a violent earthquake, the ancient Atalantis of Plato was sunk. What would be the consequence of such a mighty revolution? The sea would necessarily rush in from all quarters, and from what is now called the Atlantic Ocean; and vast continents, perhaps those which we now inhabit, would, of course, be left dry. This great revolution might be effected by the sudden failure of some immense cavern in the interior part of the globe, and an universal deluge would infallibly succeed. I should rather incline to think,

* See proofs, art. xix.

that such a revolution would not be suddenly accomplished, but that it would require a very long period. However these conjectures stand, it is certain, that such a revolution has happened, and I even believe that it happened naturally; for, if a judgment of the future is to be formed from the past, we have only to attend carefully to what daily passes before our eyes. It is a fact, established by the repeated observation of voyagers *, *that the ocean has a constant motion from east to west.* This motion, like the trade-winds, is not only perceived between the tropics, but through the whole temperate climates, and as near the poles as navigators have been able to approach. As a necessary consequence of this motion, the Pacific Ocean must make continual efforts against the coasts of Tartary, China, and India; the Indian Ocean must act against the east coast of Africa; and the Atlantic must act in a similar manner against all the eastern coasts of America. Hence the sea must have gained, and will always continue to gain, on the east, and to lose on the west. This circumstance alone would be sufficient to prove the possibility of the change of sea into land, and of land into sea. If such is the natural effect of the sea's motion from east to west, may it not reasonably be supposed, that Asia, and all the eastern continent, is the most ancient country in the world? and that Europe, and part of

* Varen. Geogr. Gen. p. 119.

Africa, especially the west parts of these continents, as Britain, France, Spain, &c., are countries of a more recent date? Both history and physics concur in establishing this hypothesis.

But, beside the constant motion of the sea from east to west, other causes concur in producing the effect just mentioned. There are many lands lower than the level of the sea, and are defended by a narrow isthmus of rock only, or by banks of still weaker materials. The action of the waters must gradually destroy these barriers; and, consequently, such lands must then become part of the ocean. Besides, the *mountains are daily diminishing, part of them being constantly carried down to the valleys by rains**. It is likewise well known, that every little brook carries earth, and other matters, from the high grounds into the rivers, by which they are at last transported to the ocean. By these means the bottom of the sea is gradually filling up, the surface of the earth is approaching to a level, and nothing but time is wanting for the sea's successively changing places with the land.

I speak not here of causes removed beyond the sphere of our knowledge, of those convulsions of nature, the slightest effort of which would be fatal to the globe. The near approach of a comet, the absence of the moon, or the intro-

* Ray's Discourses, p. 226. Plot. Hist. Nat. &c.

duction of a new planet into the system, &c., are suppositions upon which the imagination may rove at large. Causes of this kind will produce any effect we choose. From a single hypothesis of this nature, a thousand physical romances might be composed, and their authors might dignify them with the title of *Theory of the Earth.* As an historian, I reject these vain speculations: they depend upon mere possibilities, which, if called into action, necessarily imply such a devastation in the universe, that our globe, like a fugitive particle of matter, escapes observation, and is no longer worthy of our attention. But, to give consistency to our *ideas, we must take the earth as it is, examine its different parts with minuteness, and, by induction,* judge of the future from what at present exists. We ought not to be affected by causes which seldom act, and whose action is always sudden and violent. These have no place in the ordinary course of nature. But operations uniformly repeated, motions which succeed one another without interruption, are the causes which alone ought to be the foundation of our reasoning.

Some examples shall be given: we shall combine particular effects with general causes, and give a detail of facts, which will illustrate and explain the different alterations that the earth has undergone, whether by irruptions of the sea upon the land, or by the sea's retiring from lands which it formerly covered.

That irruption which gave rise to the Medi-

terranean * is undoubtedly the greatest †. The ocean runs with prodigious rapidity through a narrow passage between two promontories ‡, and then forms a vast sea, which, exclusive of the Black Sea, is about seven times larger than the kingdom of France. *The motion through the Straits of Gibraltar is contrary to the motion in every other strait.* The general motion of the sea is from east to west; but, in the Straits of Gibraltar, it is from west to east; an incontestible proof, that the Mediterranean Sea is not an ancient gulf, but that it has been formed by an irruption, produced by some accidental cause, such as an earthquake swallowing up the barrier, or a violent effort of the ocean, occasioned by the wind, and forcing its way through the bank between the two promontories of Gibraltar and Ceuta. This opinion is supported by the testimony of the ancients ‖, who inform us, that there was a time when the Mediterranean had no existence. It is likewise confirmed by natural history, and by observations upon the strata on the opposite coasts of Africa and Spain, where, as in neighbouring mountains, the beds of earth and stone are precisely the same at equal levels.

When the ocean forced this passage, it ran through the Straits with much more rapidity

* Proofs, art. xi. and xix.

† Ray's Discourses, p. 209; Plot. Hist. Nat. &c.

‡ Phil Trans. abridged, vol. ii. p. 289.

‖ Diodorus Siculus, Strabo.

than at present, and instantly deluged that large tract of land which formerly joined Europe to Africa. The waters covered all the grounds which were lower than the level of the ocean; and no part of them is now to be seen, except the tops of some of the mountains, such as part of *Italy, Sicily, Malta, Corsica, Sardinia, Cyprus, Rhodes,* and the *islands of the Archipelago.*

I have not mentioned the Black Sea as an effect of this irruption; because the quantity of water it receives from the Danube, the Nieper, the Don, and other rivers, is more than sufficient both to form and support this sea. Besides, it runs with great rapidity through the Bosphorus into the Mediterranean*. It may even be supposed that the Black and Caspian Seas were only two large lakes, which were perhaps joined by a narrow communication, or rather by a morass, or small lake, uniting the Don and the Wolga about Tria, where these two rivers run very near each other. It is likewise probable, that these two seas, or lakes, were formerly of a much greater extent; for the large rivers which fall into the Black and Caspian Seas must have gradually brought down a quantity of earth and sand sufficient to stop up the communication, and to form that neck of land by which these two seas are divided. We know, that large rivers, in a course of time, block up seas, and form new lands, as in the province at the mouth

* Phil. Trans. abridged, vol. ii. p 289.

of the Yellow River in China; Louisiana at the mouth of the Missisippi; and the northern part of Egypt, which derived its existence * from the inundations of the Nile †. Such quantities of earth are brought down, by the rapidity of the Nile, from the interior parts of Africa, and deposited during the inundations, that you may dig fifty feet deep before you can reach the bottom of the slime and mud. Louisiana, and the province of the Yellow River, have, in the same manner, been originally formed by the slime of rivers.

Farther, the Caspian Sea is a real lake. It has no communication with any other sea, not even with the Lake Aral, which appears to have been a part of it, being only separated by a large tract of sand, in which neither river nor canal for carrying off the waters has been discovered. This sea, therefore, has no external communication with any other; and I doubt much if there is any reason to suspect a subterraneous communication with the Black Sea, or with the Gulf of Persia. The Caspian, it is true, receives the Wolga, and several other rivers, which appear to furnish as much water as is lost by evaporation. But, independent of the difficulties attending such calculations, if it communicates with any other sea, a uniform and rapid current towards the place of communication would be an infallible consequence; but nothing of this kind has yet been discovered. Travellers of the best

* Shaw's Travels.

† Proofs, art. xix.

credit assure us of the contrary. We, therefore, conclude, that the Caspian Sea receives just as much water from the rivers and clouds as it loses by evaporation.

It is not improbable, that the Black Sea will, in time, be entirely divided from the Mediterranean; and that the Bosphorus will be choked up, whenever the rivers shall have accumulated a sufficient quantity of materials to bring about that effect. It is impossible to fix the æra of this event: but time and the diminution of waters in rivers, in proportion as the mountains are lowered by the causes mentioned above, will one day exhibit this phænomenon to the world.

The Caspian and Black Seas should, therefore, be considered rather as lakes than as gulfs of the ocean; because they exactly resemble other lakes which receive a number of rivers without any visible outlet, as the Dead Sea, several lakes in Africa, and elsewhere. Besides, the saltness of these two seas is not nearly equal to that of the Mediterranean or of the ocean; and, it is an agreed point, that the navigation in the Caspian and Black Seas, on account of their numberless shoals, rocks, and banks, is so extremely hazardous, that small vessels only can be used in them with safety. This circumstance farther proves, that these seas ought not to be considered as gulfs of the ocean, but as vast collections of water amassed by large rivers.

If the isthmus which separates Africa from Asia were cut, it would necessarily create a great

irruption of the sea upon the land. This junction was formerly projected by the kings of Egypt, and adopted since by the Califs. I doubt whether the pretended communication between the Red Sea and Mediterranean be sufficiently established. The Red Sea is a narrow branch of the ocean: through its whole extent, not a single river runs into it from the Egyptian side, and very few from the opposite. This sea will not, therefore, be subject to diminution, like those seas or lakes which are actually impaired by the slime and sand brought down by large rivers. The Red Sea receives all its waters directly from the ocean, and the motion of the tides in it are very discernible; of course, it must be affected by the general motions of the ocean. The Mediterranean, on the other hand, must be lower than the ocean; because the current through the Straits is exceedingly rapid. Besides, it receives the Nile, which runs parallel to the west coast of the Red Sea, and passes through the longest extent of Egypt, which is a very low country. From these circumstances, it is at least probable, that the Red Sea is higher than the Mediterranean, and, consequently, that, if the isthmus of Suez were cut, a great inundation, and a considerable augmentation of the Mediterranean would ensue; especially if the waters were not restrained by dikes and sluices, placed at proper distances. This precaution was probably used, if ever the ancient canal subsisted.

But, not to spend time on conjectures, which,

however well founded, may perhaps appear rash, we shall give some certain and recent examples of the changes of sea into land, and of land into sea *. At Venice, the bottom of the sea is constantly rising: if the canals had not been carefully kept clean, the moats and city would, long ere now, have formed a part of the continent. The same thing may be said of most harbours, bays, and mouths of rivers. In Holland, the bottom of the sea is elevated in many places; the gulf of Zuderzee and the straits of the Texel cannot receive such large vessels as formerly. At the mouth of almost every river, we find small islands, and banks of earth and sand brought down from the higher grounds; and it is incontrovertible, that the sea is constantly dammed up, wherever great rivers empty themselves. The Rhine is lost in the sands which itself has accumulated. The Danube, the Nile, and all large rivers, after having transported great quantities of slime, sand, &c., never more arrive at the sea by a single channel; they split into branches, the intervals of which consist of the materials which they themselves have transported. Marshes are daily drained; lands, abandoned by the sea, are now plowed and sown; we navigate whole countries now covered by the waters; in a word, we see so many instances of land changed into water, and water into land, that we must be convinced of the continual, though slow, pro-

* Proofs, art. xix.

gress of such changes in all places. Hence the gulfs of the ocean will in time become continents, the isthmuses will be changed into straits; and the tops of the mountains will be metamorphosed into shoaly rocks in the sea.

The waters, therefore, have covered, and may still cover, every part of the earth which is now dry. Hence our astonishment at finding the productions of the sea dispersed every where, and a composition of bodies, which could not be effected by any other means than the operation of the waters, ought for ever to cease. We have already explained how the horizontal strata of the earth were formed. But those perpendicular fissures, which are equally diffused through rocks, clays, and every constituent material of the globe, remain to be considered *. The perpendicular fissures are indeed placed at greater distances from each other than the horizontal; and the softer the matter, the more distant are the fissures. In marble and hard stone, the perpendicular fissures are only a few feet asunder. If the mass of rock be extensive, the distance betwixt the fissures is some fathoms: sometimes they extend from the summit to the base of the rock, and sometimes they terminate after arriving at a horizontal fissure. They are uniformly perpendicular in the strata of all calcarious substances, as chalk, marls, marble, &c. But they are more oblique, and less regularly situated, in vitrescent bodies, brown free-stone, and rocks of

* Proofs, art. xvii.

flint, where they are often adorned with crystals and other minerals. In quarries of marble, or of calcarious stone, the fissures are filled with spar, gypsum, gravel, and an earthy sand, which contains a considerable portion of chalk. In marls, and every other species of earth, except sandstone, the perpendicular fissures are either empty, or filled with such matters as have been transported thither by water.

The cause of perpendicular fissures is easily investigated. As the various materials which constitute the different strata were transported by the waters, and deposited in the form of sediments, they would at first be in a very diluted state, and would gradually harden and part with the superfluous quantity of water they contained. In the process of drying, they would naturally contract, and of course split at irregular distances. These fissures necessarily assumed a perpendicular direction; because, in this direction, the action of gravity of one particle upon another is equal to nothing; but it acts directly opposite in a horizontal situation: the diminution in bulk could have no sensible effect but in a vertical line. I say, the contraction of the parts in drying, not the contained water forcing an issue, as has been alleged, is the cause of perpendicular fissures; for I have often remarked, that the sides of these fissures, through their whole extent, correspond as exactly as the two sides of a split piece of wood. Their surfaces are rude and irregular. But, if they had taken their rise from the motion of water, they

would have been smooth and polished. Hence these fissures must have been produced, either suddenly or gradually, by drying and contracting, like the cracks and fissures in green wood; and the greatest part of the water the bodies contained must have evaporated through the pores. In the chapter upon minerals, we shall demonstrate, that some part of the original water still remains in stones and several other substances; and that crystals, minerals, and some other bodies, owe their existence to this water.

Perpendicular fissures vary greatly as to the extent of their openings. Some are about half an inch, or an inch, others a foot, or two feet; some extend several fathoms, and give rise to those vast precipices which so frequently occur *between opposite parts of the same rocks in the Alps and other high mountains. It is plain, that the fissures, the openings of which are small, have been occasioned solely by drying.* But those which extend several feet are partly owing to another cause; namely, the sinking of the foundation upon one side, while that of the other remained firm. If the base sinks but a line or two, when the height of the rock is considerable, an opening of several feet, or even fathoms, will be the consequence. When rocks are founded on clay or sand, they sometimes slip a little to a side; and the fissures are of course augmented by this motion. I have not hitherto mentioned those large openings, those prodigious cuts, which are to be met with in rocks

and mountains: these could not be produced by any other means than the sinking of immense subterraneous caverns, which were unable longer to sustain their incumbent load. But these cuts or intervals in mountains are not of the same nature with perpendicular fissures: they appear to have been ports opened by the hand of Nature for the communication of nations. This seems to be the intention of all large openings in chains of mountains, and of those straits by which different parts of the ocean are connected; as the Straits of Thermopylæ, of Gibraltar, &c.; the gaps or ports in Mount Caucasus, the Cordeliers, &c. A simple separation, by the drying of the matter, could not produce this effect: large portions of earth must have been sunk, swallowed up, or thrown down *.

These great sinkings, though occasioned by *accidental and secondary causes* †, *are leading facts* in the history of the earth, and have contributed greatly in changing the appearance of its surface. Most of them have been produced by subterraneous fires, the explosions of which give rise to earthquakes and volcanos. The force of inflamed matter, shut up in the bowels of the earth, is irresistible ‡. By the action of subterraneous fires, whole cities have been swallowed up, mountains, and large tracts of country, have been overturned and rendered unfit

* Proofs, art. xvii. † Ibid.

‡ Agricola de rebus quæ effluunt e terra. Phil. Trans. abridged, vol ii. p. 391. Ray's Discourses, p. 272.

for the habitation of men. But, though this force be great, though its effects appear to be prodigious, we cannot assent to the opinions of some authors, who suppose that these subterraneous fires are only branches of an immense abyss of flame in the centre of the earth. Neither do we credit the common notion, that these fires have their seat at a great depth below the surface; for matter cannot begin to burn, or at least the inflammation cannot be supported, without air. In examining the materials which issue from volcanos, even in their most violent eruptions, it is easy to perceive that the furnace *is not very deep, and that the inflamed substances are the same with those on the top of* the mountain, only disfigured by calcination and the melting of the metallic particles they contain. To be convinced that the matters thrown out by volcanos come not from any considerable depth, we need only attend to the height of the mountain, and consider the immense force which would be necessary to project stones and minerals to the height of half a league; for Ætna, Hecla, and other volcanos, have at least that elevation.

Now, it is well known that fire acts equally on all sides; it cannot, therefore, act upwards with a force sufficient to throw large stones half a league high, without an equal re-action on the base and sides. But the sides of the mountain would very soon be pierced and blown to peices by this re-action; because the materials of which it consists are not more dense or firm

than those which are projected. How, then, can it be imagined, that the cavity, which must be considered as the tube or cannon, could possibly resist a force necessary to raise such heavy bodies to the mouth of the volcano? Besides, suppose the cavity deeper, as the external orifice is not great, it would be impossible for so large a quantity of liquid and burning matters to issue forth at a time, without clashing against each other, and against the irregular sides of the cavity; and, in passing through so long a space, they would be in danger of cooling and congealing. *Rivers of melted sulphur and bitumen, projected from volcanos along with stones and minerals, run from the tops of the mountains into the plains. Is it natural to think, that matter so fluid, so little able to resist violent action, could be projected from a very great depth?* Every observation which can be made on this subject will tend to prove, that the fire in volcanos is not very distant from the tops of the mountains, and never descends so low as the level of the plains *.

This account of volcanos, however, is not inconsistent with their being the cause of considerable earthquakes; neither does it contradict the communication of one volcano with another, by means of subterraneous passages †. But the depth of the furnace is the object of our present investigation; and it cannot be very dis-

* Borelli de incendiis Ætnæ.

† Phil. Trans. abridged, vol. ii. p. 392.

tant from the mouth of the volcano. To produce an earthquake in a plain, it is not necessary that the bottom of the volcano should be below the level of that plain, nor that there should be subterraneous cavities filled with the same burning matter under the plain. A violent explosion, with which eruptions are uniformly accompanied, may, like that of a powder-magazine, give such a concussion as to produce, by its re-action, an earthquake of considerable extent.

I mean not to say, that there are no earthquakes which derive their existence from subterranean fires*; but that there are earthquakes produced solely by the explosion of volcanos. In confirmation of what has been said upon this subject, volcanos seldom or never appear in plains; on the contrary, their mouths, or craters, are always found on the tops of the highest mountains. If the subterraneous fire of volcanos stretched below the plains, would not *new passages be opened there during violent eruptions, rather than in the tops of the mountains,* where the resistance is greater? In the first eruption, would it not have been easier to pierce a plain, than a mountain of half a league in height?

It is not difficult to discover the reason why volcanos appear only in mountains. Greater quantities of minerals, sulphur, and pyrites, exist in mountains, and nearer the surface, than

* Proofs, art. xvi.

in plains. The mountains have likewise this farther advantage; they are more subject to the impressions of the air, and receive more rain and moisture, by which mineral substances are capable of being fermented to such a degree as to produce actual inflammation.

To conclude, it has often been observed, that, after violent eruptions, the mountains have sunk and diminished, nearly in proportion to the quantity of matter thrown out, which is another proof that volcanos are not so deep as the base of the mountains, and even that they are not much below the summit.

In many places, earthquakes have formed considerable hollows, and even some large gaps, in mountains. All other inequalities are coeval with the mountains themselves, and owe their existence to currents in the ocean; for, in every place which has not been disturbed by accidental convulsions, the strata of mountains are parallel, and their angles correspond *. It is not difficult *to distinguish subterraneous caverns and excavations formed by volcanos, from those* produced by water. The latter consist only of solid rocks, the sand and clay with which they were formerly filled being carried off by the water, which is the origin of caverns in hills; for those found in plains are commonly nothing but old pits and quarries, like the salt-quarries of Maestricht, the mines of Poland, &c. But natural caverns are proper to the mountains;

* Proofs, art. xvii.

the summit, or higher parts, furnish them with water which afterwards issues out to the surface wherever it can find a passage. These caverns are the sources of springs and rivers. When a large cavern of this kind is suddenly filled up by the falling of its roof, an inundation is generally the consequence *.

From these facts it is easy to perceive how much subterraneous fires have contributed to change both the surface and internal part of the globe. This cause has power sufficient to produce very great effects. But it is difficult to conceive how any sensible alterations upon the land can be introduced by the winds †. Their dominion would appear to be confined to the sea. Indeed, next to the tides, nothing has such a powerful influence upon the waters; the flux and reflux proceed with an uniform pace; their operations are always the same; but the action of the winds is capricious and violent. They rush on with irresistible fury, and excite such impetuous commotions, that the ocean, from a smooth and tranquil plain, in an instant is furrowed with waves, which emulate the height of mountains, and dash themselves in pieces against the shores. The surface of the ocean is subject to constant alterations from the winds. But ought not the surface of the land, which has so solid an appearance, ever to remain uninfluenced by a cause of this kind? It is consonant to ex-

* Phil. Trans. abridged, vol. ii. p. 322.

† Proofs, art. xv.

perience, however, that the winds raise mountains of sand in Arabia and Africa; that they overwhelm large plains with it; and that they frequently carry these sands many leagues into the sea, where they accumulate in such quantities as to form banks, downs, and even islands *. It is also well known, that hurricanes are the scourge of the Antilles, of Madagascar, and of other countries, where their impetuosity is so great, that they sweep away trees, plants, and animals, together with the soil which nourished them. They drive back, they annihilate rivers, and produce new ones; they overthrow rocks and mountains; they scoop out holes and gulfs in the earth, and totally change the face of those unhappy countries which give birth to them. Happily, few climates are exposed to the violence of those dreadful agitations of the air.

But the greatest changes upon the surface of the earth are occasioned by rains, rivers, and torrents from the mountains. These derive their origin from vapours raised by the sun from the surface of the ocean, and are transported by the winds through every climate. The progress of these vapours, which are supported by the air, and transported at the pleasure of the winds, is interrupted by the tops of the mountains, where they accumulate into clouds, and fall down in the form of rain, dew, or snow. At first, these

* Bellarmin. de ascen. mentis in Deum. Varen. Geog. p. 282, Voyag. de Pyrard. tom. i. p. 470.

waters descended into the plains without any fixed course*; but they gradually hollowed out proper channels for themselves. By the power of gravity, they ran to the bottom of the mountains, and, penetrating or dissolving the lower grounds, they carried along with them sand and gravel, cut deep furrows in the plains, and thus opened passages to the sea, which always receives as much water by rivers as it loses by evaporation. The windings in the channels of rivers have uniformly corresponding angles on their opposite banks; and as mountains and hills, which may be regarded as the banks of the valleys by which they are separated, have likewise sinuosities with corresponding angles, this circumstance seems to demonstrate, that the valleys have been gradually formed by currents of the ocean, in the same manner as the channels of rivers have been produced.

The waters which run upon the surface, and support the verdure and fertility of the soil, compose not perhaps one half of the quantity that is produced by vapour. Numberless veins of water sink deep into the bowels of the earth. In some places, you are certain of obtaining water by digging; in others, none can be found. In almost all the valleys and low grounds, at a certain depth, water is uniformly to be met with. But, in all high gronnds, it is impossible to extract water from the bowels of the earth. It must be collected from the heavens. There

are extensive countries where no wells can be obtained; there men, and other animals, are supplied with drink from cisterns and pools. In the east, and especially in Arabia, Egypt, and Persia, wells and springs are great and valuable rarities. To supply their place, the inhabitants have been obliged to make large reservoirs to collect the water that falls from the heavens. These works, projected and executed from public necessity, constitute the most beautiful and magnificent monuments of the east. Some eastern reservoirs have more than two square leagues of superfices, and fertilize whole provinces by numberless ducts and canals let out from all sides. But, in plain countries, furnished with large rivers, it is impossible to break the surface of the earth without finding water. In camps situated in the neighbourhood of rivers, it often happens that every tent may have its own well, by giving a few strokes with a pick-ax.

Most of the water, so liberally diffused through low grounds, comes from the neighbouring hills and eminenees. During great rains, or the sudden melting of snow, part of the water runs upon the surface; but most of it penetrates the earth and rocks, by means of small chinks and fissures. This water rises again to the surface, whenever it can find an issue; but it often drills through sands, and creeps along till it finds a bottom of clay, or hard earth, and there forms subterraneous lakes, brooks, and perhaps rivers, of which the channels are for ever buried in oblivion. Subterraneous rivers, however, must

follow the general law of nature, and uniformly run from the higher to the lower ground. Their waters must of course either fall at last into the sea, or be collected in some low place, whether at the surface or in the bowels of the earth: for there are several lakes which neither receive nor give rise to any river. A still greater number receive no considerable river, but are the sources of the largest rivers on earth; as the lakes from which the river St. Lawrence issues; the lake Chiamè, from which two large rivers arise, that water the kingdoms of Asem and Pegu; the lakes of Assiniboil in America; those of Ozera in Muscovy; those that give rise to the Bog and the Irtis, and many others*. It is plain, that these lakes must derive their existence from the waters of superior grounds, running through subterraneous passages. Some, indeed, have affirmed, that lakes are to be met with on the tops of the highest mountains. But this is incredible; for the lakes found on the Alps, and other elevated situations, are all overtopped by higher mountains, and derive their origin from the waters which run down the sides, or are filtered through the bowels of these superior eminences, in the same manner as the lakes in valleys are supplied.

From this reasoning, the existence of subterraneous collections of water, especially under large plains, is apparent †: for mountains, hills, and heights of every kind, are exposed on all

sides to the weather. The waters which fall upon their summits, and upon elevated plains, after penetrating the earth, must, from the declivity of the ground, break out at many places in the form of springs and fountains: of course, little water will be found in the bowels of mountains. But, in plains, as the water filtrated through the earth can find no issue, it must be collected in subterraneous caverns, or dispersed in small veins, among sand and gravel. This is the origin of the water so universally diffused through low grounds. The bottom of a pit, or well, is only a small artificial bason, into which the water insinuates itself from the higher grounds. At first it generally falls in by drops; but afterwards, when the passages become more open, it receives fresh supplies from greater distances, and runs in small continued veins or rills. To this circumstance it is owing, that although water may be found in any part of a plain, only a certain number of wells can be supplied. This number is in proportion to the quantity of water diffused, or rather to the extent of the higher grounds from which it comes.

To find water, it is unnecessary to dig below the level of a river. It is commonly found at smaller depths. The water of rivers seldom spreads far in the earth by filtration. Even what is found in the earth below the level of rivers, is not derived from them; for, in rivers which have been dried up, or whose courses have been changed, no greater quantity of water is

obtained by digging, than in the neighbouring ground at an equal depth. Five or six feet of earth is sufficient to contain water, and to prevent its escape: I have often remarked, that the banks of rivulets or pools have no sensible moisture at the distance of six inches from the water. It is true, the filtration is always in proportion to the penetrability of the ground. But, upon examining the stagnating pools with a sandy bottom, it is remarkable that the moisture spreads but a few inches. Neither is the extent of it great in a vegetable soil, which is much more loose and porous than sand or hard earth. A garden bed, though plentifully watered, communicates little or no moisture to those adjoining. I have examined level heaps of garden earth, of six or eight feet thick, which had remained undisturbed for some years, and found that the rain-water had never reached above three or four feet deep. I have made the same observation upon earth which had lain 200 years in ridges: below the depth of three or four feet, it was as dry as dust. Hence the spreading of water, by filtration alone, is not so extensive as has generally been imagined. Very little can descend in this way to the bowels of the earth. But water, by its own gravity, descends from the surface to the greatest depths. It sinks through natural conduits, or forces passages for itself: it follows the roots of trees, the fissures of rocks, or interstices in the earth. It divides and expands on all hands into an infinite number of small branches or rills: and uniformly

descends till its progress is stopped by clay or a solid earth, where it accumulates and breaks out to the surface in form of a spring or fountain.

It would be no easy task to make an exact calculation of the quantity of subterraneous waters which have no apparent issue*. Many authors pretend that it greatly surpasses all the waters on the surface: not to mention those who think that the interior part of the globe is entirely filled with water, it is imagined by some, that there is an infinite number of rivers, rills, and lakes, in the bowels of the earth. But this opinion seems to have no proper foundation; and it is probable, that the quantity of subterraneous waters, which never appear at the surface, is very inconsiderable; for, if the number of subterraneous rivers were so great, Why do we never see any of their mouths break out, like springs, on the surface? Besides, rivers produce considerable changes on the surface of the earth; they carry off the soil; they wear away the most solid rocks, and remove every thing that opposes their passage. The same effects would result from subterraneous rivers. But no such changes have ever been discovered; nothing below the surface is displaced; the different strata every where preserve their parallel and primitive position: and it is only in very few places that subterraneous veins of water, of any consideration, have been discovered. Thus, the internal operation of water is not great; but, as

* Proofs, art. x. xi. and xviii.

it is divided into an infinity of small veins, which are often shut up by numberless obstacles, it gives rise to many substances, which are totally different, both in form and structure, from those of the primitive matter.

From what has been advanced, we may conclude, that the flux and reflux of the ocean have produced all the mountains, valleys, and other inequalities on the surface of the earth; that currents of the sea have scooped out the valleys, elevated the hills, and bestowed on them their corresponding directions; that the same waters of the ocean, by transporting and depositing earth, &c., have given rise to the parallel strata; that the waters from the heavens gradually destroy the effects of the sea, by continually diminishing the height of the mountains, filling up the valleys, and choking the mouths of rivers; and, by reducing every thing to its former level, they will, in time, restore the earth to the sea, which, by its natural operations, will again create new continents, interspersed with mountains and valleys, every way similar to those which we now inhabit.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE I.

Of the Formation of Planets.

As natural history is our proper subject, we would willingly dispense with astronomical observations. But, as the earth is so nearly related to the heavenly bodies, and as observations of this kind illustrate more fully those doctrines we have already advanced, it is necessary to give some general ideas concerning the formation, motion, and figure of the earth, and other planets.

The earth is a globe of about 3000 leagues in diameter; it is situated 30 millions of leagues from the sun, round which it revolves in 365 days *.. This annual revolution is the effect of

* This was the general opinion of astronomers in the year 1745, when I composed the treatise on the formation of the planets. But later observations, and particularly those derived from the transit of Venus over the sun's disk in 1769, show, that this distance of thirty millions should be augmented three or four millions of leagues. It is for this reason that, in the *Epoques de la Nature*, I have always reckoned the mean

two forces; the one may be considered as an impulse from right to left, or from left to right; the other as an attraction from above downwards, or from below upwards, to a common centre. The direction and quantity of these forces are combined, and so nicely adjusted, that they produce a uniform motion in an ellipse approaching to a circle. Like the other planets, the earth is opaque, throws out a shadow, and reflects the rays of the sun, about which it revolves in a time proportioned to its relative distance and density. It likewise revolves about its own axis in 24 hours; and its axis is inclined to the plane of its orbit 66½ degrees. Its figure is that of a spheroid, the two axes of which differ from each other about an 175th part; and it revolves round the shortest axis.

distance of the sun from the earth to be thirty-three millions of leagues, instead of thirty. This remark was necessary to prevent the suspicion of my having contradicted myself.

I must farther remark, that the sun is not only thirty-three or thirty-four millions of leagues distant from the earth, but, from the same observations, it has likewise been discovered, that the volume of the sun is a tenth part larger than was formerly supposed; and, consequently, that the whole mass of the planets is only an eight hundredth part of that of the sun, and not a six hundredth and fiftieth part, as I had advanced from the information we possessed in the year 1745. This difference strengthens the probability that the matter of the planets was projected from the body of the sun *.

* According to Lalarde, the mean distance of the earth from the sun is 34,557,480 leagues, of 2,283 toises each. Professor Vince calculates it at 93,474,875 miles; and both Hutton and Young have en-

W.

These are the principal phænomena of the earth, the results of discoveries made by means of geometry, astronomy, and navigation. It is unnecessary here to enumerate the proofs and observations by which these facts have been established.* We shall confine our remarks to such objects as are still doubtful; and shall therefore proceed to give our ideas concerning the formation of planets, and the changes they have undergone, previous to their arriving at the state in which we now perceive them. To the many systems and hypotheses which have been framed concerning the formation of the earth, and the different states it has passed through, we may be allowed to add our own conjectures, especially as we are determined to support them with a superior degree of probability; and we are the more encouraged to deliver our notions on this subject, because we hope to enable the reader to distinguish between an hypothesis which consists only of possibilities, and a theory supported by facts; between a system, such as we are about to give, of the formation and primitive state of the earth, and a physical history of its real condition, which has been delivered in the preceding discourse.

Galileo traced the laws of falling bodies; and Kepler observed, that the areas which the principal planets describe in moving round the sun, and those of the satellites round their principal planets, were proportioned to the periods of their revolutions, and that these periods were as the square roots of the cubes of their distances

from the sun, or from the principal planets. Newton discovered that the power of gravity extended to the moon, and retained it in its orbit; that the force of gravity diminished in exact proportion to the squares of the distances, and, consequently, that the moon is attracted by the earth; that the earth, and all planets, are attracted by the sun; and, in general, that all bodies which revolve about a centre, and describe areas proportioned to the periods of their revolution, are attracted by that luminary. Gravity, therefore, is a general law of nature. The planets, comets, the sun, the earth, are all subject to its laws; and it is the source of that harmony which prevails in the universe. Nothing in physics is better established than the existence of this power in every material body. Repeated experience has confirmed the effects of its influence, and the labour and ingenuity of geometers have determined its quantity and. relations.

This general law being once discovered, the effects of it would be easily explained, if the action of those bodies which produce them were not too complicated. A slight view of the solar system will convince us of the difficulties which attend this subject. The principal planets are attracted by the sun, the sun by the planets, the satellites by the principal planets, and each planet attracts all the others, and is attracted by them. All these actions and re-actions vary according to the quantities of matter and the dis-

even irregularities. How are so many relations to be combined and estimated? Among such a number of objects, how is it possible to trace any individual? These difficulties, however, have been surmounted; the reasonings of theory have been confirmed by calculation; every observation has produced a new demonstration; and the systematic order of the universe is now laid open to every man who is able to distinguish truth from error.

The force of impulsion, or what is commonly called the centrifugal force, is still unknown; but it affects not the general theory. It is evident, that, as the attractive force continually draws all the planets towards the sun, they would fall in a perpendicular line into that luminary, if they were not kept at a distance by some other power, forcing them to move in a straight line. If, again, this impulsive force were not counteracted by that of attraction, all the planets would fly off in the tangents of their respective orbits. This progressive or impulsive force was unquestionably at first communicated to the planets by the Supreme Being. But, in physical subjects, we ought, as much as possible, to avoid having recourse to supernatural causes; and, I imagine, a probable reason may be assigned for the impulsive force of the planets, which will be agreeable to the laws of mechanics, and not more surprising than many revolutions that must have happened in the universe.

The sphere of the sun's attraction is not limited by the orbits of the planets, but extends to

an indefinite distance, always decreasing according as the squares of the augmented distances. The comets, it is evident, which escape our sight in the heavenly regions, are, like the planets, subject to the attraction of the sun, and by it their motions are regulated. All these bodies, the directions of which are so various, move round the sun, and describe areas proportioned to their periods, the planets in ellipses, more or less circular, and the comets, in narrow ellipses of vast extent. The motions, therefore, both of planets and comets, are regulated by impulsive and attractive forces continually acting upon them, and obliging them to describe curves. But it is worthy of remark, that comets run through the system in all directions; that the inclinations of the planes of their orbits are so very different, that though, like the planets, they be subject to the law of attraction, they have nothing in common with regard to their progressive or impulsive motions, but appear, in this respect, to be absolutely independent of each other. The planets, on the contrary, move round the sun in the same direction, and nearly in the same plane, the greatest inclination of their planes not exceeding 7½ degrees. This similarity in the position and motion of the planets indicates, that their impulsive and centrifugal forces must have originated from one common cause.

May we not conjecture, that a comet falling into the body of the sun might drive off some parts from its surface, and communicate to

retain? This conjecture appears to be as well founded as that of Mr. Leibnitz, which supposed the earth and planets to have formerly been suns; and his system, of which an abridgment will be given in art. v., would have been more comprehensive, and more consonant to probability, if it had embraced the above idea. We agree with him, that this effect was produced at the time when God is said by Moses to have separated the light from the darkness; for, according to Leibnitz, the light was separated from the darkness when the planets were extinguished. But, on our supposition, there was a real physical separation; because the opaque bodies of the planets were detached from the luminous matter of which the sun is composed *.

These expressions, however, are not correct; for the matter of the planets, when projected from the sun, was equally luminous as that of the sun itself, and the planets became not opaque till their state of fluid brightness had ceased: the duration of this state in several kinds of matter I determined by experiment; and, from analogy, I calculated the continuation of this bright state in each of the planets †. Besides, as the torrent of matter, projected from the body of the sun by the comet, traversed the immense atmosphere of

* If the Count de Buffon had known, that the nucleus of the sun was a solid and opaque matter, a discovery lately made by the ingenious Dr. Wilson of Glasgow, his hypothesis would have laboured under fewer difficulties.

† See Epoques de la Nature.

that luminary, it carried off the volatile, aqueous, and aërial parts of which the seas and atmospheres of the different planets are now composed. Hence we may conclude, that the matter of the planets is the same, in every respect, with that of the sun, and that there is no other difference but in the degree of heat, which is extreme in the sun, and greater or smaller in the planets, according to the compound ratio *of their thickness and density.*

This notion concerning the cause of the centrifugal force of the planets will appear to be less exceptionable, after we have collected the analogies, and estimated the degrees of probability by which it may be supported. We shall first mention, that the planets move in one common direction, namely, from west to east. By the doctrine of chances, it is easy to demonstrate, that this circumstance makes it as 64 to 1, that the planets could not at all move in the same direction, if their centrifugal forces had not proceeded from the same cause.

This probability will be greatly augmented, if we consider the similarity in the inclinations of the planes of their orbits, which exceed not $7\frac{1}{2}$ degrees; for, by calculations, it has been discovered, that it is 24 to 1 against any two planets being found, at the same time, in the most distant parts of their orbits; and, consequently, 24^5, or 7,692,624 to 1, that this effect could not be produced by accident; or, what amounts to the same, there is

this great degree of probability, that the planets have been impressed with one common moving force, from which they have derived this singular position. But nothing could bestow this common centrifugal motion, except the force and direction of the bodies by which it was originally communicated. We may, therefore, conclude, that all the planets have probably received their centrifugal motion by *one single stroke*. Having established this degree of probability, which almost amounts to a certainty, I next inquire what moving bodies could produce this effect; and I can find nothing but comets capable of communicating motion to such vast masses.

Upon examining the course of comets, it is easy to believe that some of them must occasionally fall into the sun. The comet 1680 approached so near, that, at its perihelion, it was not more distant from the sun than a sixteenth part of his diameter; and if it returns, which is extremely probable, in the year 2255, it may then fall into the sun. This event must depend upon the accidents it meets with in its course, and the retardations it suffers in passing through the sun's atmosphere *.

We may therefore presume, with the great Newton, that comets sometimes fall into the sun. But they may fall in different directions. If they fall perpendicularly, or in a direction

* See Newt. edit. 3, p. 525.

not very oblique, they will remain in the body of the sun, serve the purposes of fuel, and, by their impulse, remove the sun from his place, in proportion to the quantity of matter they contain *. But, if a comet falls in a very oblique direction, which will most frequently happen, it will only graze the surface, or penetrate to no great depth. In this case, it may force its way past the sun, detach certain portions of his body, to which it will communicate a common impulsive motion; and these portions pushed off from the sun, and even the comet itself, may turn planets, which will revolve round this luminary in the same direction, and nearly in the same plane. A calculation, perhaps, might be made of the quantity of matter, velocity, and direction, a comet ought to have, in order to force from the sun masses equal to those which compose the six planets and their satellites. But it is sufficient here to observe, that the whole planets, with their satellites, make not a 650th part of the sun's mass †; for although the density of Saturn and Jupiter be less than that of the sun, and though the earth be four times, and the moon near five times, more dense than the sun; yet they are only atoms when compared to his immense volume.

It must be acknowledged, that, although a

* Quær. Would not such an event, by augmenting the sun's quantity of matter, and, consequently, his attractive *power, produce other changes in the solar system?*

† *See Newt. p. 405.*

650th part of a whole may seem inconsiderable, it would require a very large comet to detach this part from the sun. But, if we consider the prodigious rapidity of comets in their perihelion; the near approach they make to the sun; the density and strong cohesion of parts necessary to sustain, without destruction, the inconceivable heat they undergo; and the solid and brilliant nucleus which shines through their dark atmospheres;—it cannot be doubted that comets are composed of matters extremely dense and solid; that they contain, in small limits, a great quantity of matter; and, consequently, that a comet of no enormous size may remove the sun from his place, and give a projectile motion to a mass of matter equal to the 650th part of his body. This remark corresponds with what we know concerning the respective densities of the planets, which always decrease in proportion to their distances from the sun, having less force of heat to resist. Accordingly, Saturn is less dense than Jupiter, and Jupiter much less than the earth. Thus, if the density of the planets, as Newton alleges, be in proportion to the quantity of heat they support, Mercury will be seven times denser than the earth, and 28 times denser than the sun, and the comet 1680, 28,000 times more dense than the earth, or 112,000 times denser than the sun. Now, supposing the quantity of matter in this comet to be equal to a ninth part of the sun, or allowing it to be only 100dth part

of the bulk of the earth, its quantity of matter would still be equal to a 900dth part of the sun: hence a body of this kind, which would be *but a small comet, might push off from* the sun a 900dth or a *650th* part, especially when the amazing rapidity of comets, in their perihelion, is taken into the calculation.

The correspondence between the density of the whole planets, and that of the sun, deserves also to be noticed. Upon and near the surface of the earth, there are substances 1400 or 1600 times denser than others; the densities of air and gold are nearly in this proportion. But the interior parts of the earth and planets are more uniform, and differ little with regard to density; and the correspondence in the density of the planets and that of the sun is so great, that, out of 650 parts, which comprehend the whole density of the planets, there are more than 640 nearly of the same density with the solar matter; and there are only ten of those 650 which are of a superior density; for the density of Saturn and Jupiter is nearly the same with that of the sun; and the quantity of matter in those two planets is at least 64 times greater than what is contained in the four inferior planets, Mars, the Earth, Venus, and Mercury. We may, therefore, conclude, that, in general, the matter of the planets is very nearly of the same kind with the solar matter, and, of course, that the former may have been separated from the latter.

To this theory it may be objected, that, if the planets had been driven off from the sun by a comet, in place of describing circles round him, they must, according to the law of projectiles, have returned to the same place from whence they had been forced; and, therefore, that the projectile force of the planets cannot be attributed to the impulse of a comet.

I reply, that the planets issued not from the sun in the form of globes, but in the form of torrents, the motion of whose anterior particles must have been accelerated by those behind, and the attraction of the anterior particles would also accelerate the motion of the posterior; and that this acceleration, produced by one or both of these causes, might be such as would necessarily change the original motion arising from the impulse of the comet, and that, from this cause, might result a motion similar to what takes place in the planets, especially when it is considered, that the shock of the comet removes the sun out of its former station. This reasoning may be illustrated by an example. Suppose a musket-ball discharged from the top of a mountain, and that the force of the powder was sufficient to push it beyond a semidiameter of the earth, it is certain that this ball would revolve round the earth, and return at every revolution to the place from whence it had been discharged. But, instead of a musket-ball, if a rocket were employed, the continued

action of the fire would greatly accelerate the original impulsive motion. This rocket would by no means return to the same point, like the ball; but, *cæteris paribus*, would describe an orbit, the perigee of which would be more or less distant from the earth in proportion to the greatness of the change produced in its direction by the accelerating force of the fire. In the same manner, if the original projectile force impressed by the comet on the torrent of solar matter was accelerated, it is probable, that the planets formed by this torrent acquired their present circular or elliptical movements around the sun.

The appearances exhibited in great eruptions from volcanos may give some idea of this acceleration of motion. When Vesuvius begins to groan and throw out inflamed matter, it has been often remarked, that the motion of the cloud first ejected is slower than the succeeding ones, and that they go on increasing in celerity, till at last sulphur, lava, melted metal, and huge stones are thrown up; and that, though these observe nearly the same direction, they alter considerably that of the first cloud, and elevate it to a greater height than it would otherwise have reached.

The objection will be still farther obviated, if it is considered, that the impulse of the comet must, in some degree, have communicated a motion to the sun, and removed it from its former situation; and that, although this motion may now be so small as to escape the

notice of astronomers, it may still, however, exist, and make the sun describe a curve round the centre of gravity of the system. If this be allowed, as I presume it will, the planets, instead of returning to the sun's body, would describe orbits, the perihelions of which would be as distant from the sun as the space that he at present occupies is distant from his original station.

It may be farther objected, that if motion be accelerated in the same direction, no change in the perihelion could take place. But is it credible that no change of direction can happen in a torrent whose particles succeed each other? On the contrary, it is extremely probable, that a change was actually produced sufficient to make the planets move in their present orbits.

It may still be objected, that, if the situation of the sun had been changed by the shock of a comet, it would move uniformly; and, of course, this motion being common to the whole system, no alteration would be effected. But, previous to the shock, might not the sun move round the centre of the cometary system; and might not this primary motion be augmented or diminished by the stroke of the comet? Is not this sufficient to account for the actual motion of the planets?

If none of these suppositions be admitted, may it not be presumed that the elasticity of the sun might elevate the torrent above his surface, in place of pushing it directly forward? This cir-

cumstance alone would be sufficient to remove the perihelion, and give the planets their present movements. Neither is this supposition destitute of foundation: the solar matter may be exceedingly elastic; since light, the only part of it we are acquainted with, seems, by its effects, to be perfectly elastic. I acknowledge that I cannot determine which of the causes above assigned has actually produced an alteration in the projectile force of the planets; but they at least show that such a change is not only possible, but probable, which is enough for my present purpose.

Without farther insisting on the objections which may be made against my hypothesis, or the analogical proofs that might be brought in support of it, I shall prosecute my subject, and draw the proper conclusions. Let us first examine what might happen to the planets, and particularly to the earth, when they were impressed with their projectile forces, and what was their state after their separation from the body of the sun. A projectile motion having been communicated, by the stroke of a comet, to a quantity of matter equal to a 650th part of the sun's mass, the light particles would separate from the dense, and, by their mutual attractions, form *globes of different solidities. Saturn being composed of the largest and lightest parts, would be removed to the greatest distance from the sun; Jupiter, being denser than Saturn, would have a nearer station; and so of the rest.* The largest and least solid planets are most distant, because

they received a greater projectile force than the smaller and denser; for the projectile force being proportioned to the surface to which it is applied, the same stroke would make the larger and lighter parts of the solar matter move with more rapidity than the smaller and heavier. The parts, therefore, which differed in density, would separate from each other in such a manner, that, if the density of the solar matter be equal to 100, that of Saturn will be equal to 67, of Jupiter, $= 94\frac{1}{2}$, of Mars, $= 200$, of the Earth, $= 400$, of Venus, $= 800$, of Mercury, $= 2{,}800$. But, as the attractive force acts not in proportion to the surface, but to the quantity of matter, it would retard the progress of the more dense parts of the solar matter; and it is for this reason that we find the denser planets nearest the sun, and which move round him with more rapidity than those that are more distant, and less dense.

The density and projectile motion of Saturn and Jupiter, the two largest planets in the system, have the most exact proportion. The density of Saturn is to that of Jupiter as 67 to $94\frac{1}{2}$, and their velocities are nearly as $88\frac{2}{3}$ to $120\frac{1}{72}$, or as 67 to $90\frac{11}{16}$. How rarely do pure conjectures correspond so exactly to the phænomena of nature? It is true, according to this relation between the celerity and density of the planets, the density of the earth ought not to exceed $206\frac{7}{18}$, instead of 400, which is its real density; hence it may be supposed, that the earth has now

double its original density*. With regard to the other planets, Mars, Venus, and Mercury, as their densities are only conjectural, we know not whether this circumstance would confirm or

* The density here ascribed to the earth is too great with relation to the quickness of its motion round the sun, and ought to be a little diminished, for a reason which had formerly escaped me. The moon, which, in this computation, should be regarded as forming a part of the earth, is less dense in the ratio of 702 to 1,000, and the lunar globe is $\frac{1}{49}$th of the bulk of the terrestrial. Hence, if the moon were as large as the earth, we should diminish the density of the latter 400 in the ratio of 1,000 to 702, which produces 281, *i. e.* 119 of diminution in the density 400. But, as the moon in only $\frac{1}{49}$th part of the bulk of the earth, it will produce only $\frac{119}{49}$, or $2\frac{3}{7}$ths of diminution. Consequently, the density of our globe, with relation to its celerity, instead of $206\frac{7}{18}$, ought to be estimated at $206\frac{7}{18}+2\frac{3}{7}$, *i. e.* nearly 209. Besides, we may suppose that our globe, at the beginning, was less dense than it is at present, and that it is become much more compact both by cooling, and by the sinking of vast caverns with which its interior parts abounded. This opinion accords with those revolutions which happened, and still continue to happen, both on the surface of the earth, and even at considerable depths. By the aid of this fact, we are enabled to explain the possibility that the waters of the sea were formerly 2,000 fathoms above those parts of the globe which are now inhabited; for these waters would still cover the whole surface of the earth, if, by immense depressions, different parts had not sunk, and formed those receptacles for the waters which at present exist.

If we suppose the diameter of the globe to be 2,863 leagues, it would be two leagues more when covered with 2,000 fathoms of water. This difference in the bulk of the earth, produced by the sinking of the waters, gives an augmentation of a $\frac{1}{477}$ th part of its density. This augmentation of the density, or diminution of the bulk of the globe, may be

weaken our hypothesis. Newton says, that the densities of the planets are proportioned to the degrees of heat they are exposed to; and it is in consequence of this idea that we have mentioned Mars as being one time less dense than the earth, Venus one time, Mercury seven times, and the comet 1680, 28,000 times denser than the earth. But, if we attend to Saturn and Jupiter, the two principal planets, we will find, that this supposed proportion between the densities of the planets and the heat they sustain, is not well founded: for, according to this hypothesis, the density of Saturn would be as $4\frac{7}{18}$, and that of Jupiter as $14\frac{17}{22}$, instead of the proportions of 67 and $94\frac{1}{2}$; differences so great as to destroy the principles upon which they are founded. Thus, notwithstanding the regard due to the conjectures of Newton, I cannot refrain from thinking that the densities of the planets have a nearer relation to their celerities than to the degrees of heat to which they are exposed. This, indeed, is only a final cause; but the other is a physical relation, the exactness of which is remarkable in Saturn and Jupiter. It is certain, however, that the density of the earth, instead of being $206\frac{7}{8}$, is 400; and, consequently, the earth must have suffered a condensation in the proportion of $206\frac{7}{8}$ to 400.

From calculating the action of the solar heat

doubled, and perhaps tripled, by the sinking and overturning of mountains, and the consequent filling up of valleys; so that, since the waters fell upon the earth, its density may be supposed to have increased one hundredth part.

upon the planets, it appears that this heat, in general, is inconsiderable, and that it has never produced any great change in the density of each planet; for the action of the solar heat, which is weak in itself, has no influence on the density of the matter of which the planets are composed, except at their surfaces. It cannot act on the internal parts, because it penetrates to a very small depth only. Hence the total density of a planet has no relation to the heat transmitted to it by the sun.

It appears to be certain, therefore, that the density of the planets has no dependence on the solar heat, but, on the contrary, that their densities have a necessary relation with their celerities, which last increase or diminish in proportion to their distances from the sun. We have seen, that, at the general projection, the more dense parts were not removed so far from the sun as the less dense. Mercury, which is composed of the densest matter projected from the sun, remained in the neighbourhood of that luminary; while Saturn, which consists of the lightest matter, is removed to a great distance from the sun: and, as the most distant planets revolve round the sun with greater celerity than those that are nearer, it follows, that their density has a direct relation with their celerity and still more with their distance from the sun. The distances of the six planets from the sun are as 4, 7, 10, 15, 52, 95; and their densities as 2,040, 1,270, 1,000, 730, 292, 184. And if we suppose the densities to be in the inverse ratio of the distances,

they will be as 2,040, 1,160, 889½, 660, 210, 159. This last relation between their respective densities is perhaps more just than the former; because it seems to be founded on the physical cause which must have produced the difference of density in each planet.

But have the condensations of the planets no relation to the quantity of solar heat they sustain? In that case, Saturn, which is at the greatest distance from the sun, would have suffered little or no condensation; and Jupiter would be condensed from $90\frac{11}{16}$ to $94\frac{1}{2}$. Now, the sun's heat in Jupiter being to his heat in the earth as $14\frac{17}{22}$ to 400, their condensation ought to be in the same proportion. Thus, if Jupiter be condensed as $90\frac{11}{16}$ to $94\frac{1}{2}$, the earth, if it had been in the orbit of Jupiter, would have been condensed from $206\frac{7}{8}$ to $215\frac{220}{1451}$; but the earth being much nearer the sun, and receiving heat, in proportion to that of Jupiter, as 400 to $14\frac{17}{22}$, the quantity of condensation it would have undergone in the orbit of Jupiter must be multiplied by the proportion of 400 to $14\frac{17}{22}$, which will give nearly $234\frac{1}{3}$ for the condensation the earth must have received. The density of the earth was $206\frac{7}{8}$; by adding its acquired condensation, its actual density will be $400\frac{7}{8}$, which is nearly the same with 400, its real density determined by the moon's parallax. With regard to the other planets, I pretend not to give exact proportions, but only approximations, tending to show, that their densities have

a strong connexion with the celerity of their motions in their respective orbits.

The comet, by falling obliquely on the sun, as mentioned above, must have forced off from his surface a quantity of matter equal to a 650th part of his body. This matter, being in a liquid state, would at first form a torrent, of which the largest and rarest parts would fly to the greatest distances; the smaller and more dense, having received only an equal impulse, would remain nearer the sun; his power of attraction would operate upon all the parts detached from his body, and make them circulate round him; and, at the same time, the mutual attraction of the particles of matter would cause all the detached parts to assume the form of globes, at different distances from the sun, the nearer moving with greater rapidity in their orbits than the more remote.

But it may be objected, that, if the planets had been detached from the sun, they must have been burning and luminous, not cold and opaque bodies; nothing can have less resemblance to a globe of fire than a globe composed of earth and water; and, by comparison, the matter of the earth is totally different from that of the sun.

It may be replied to this objection, that the matter changed its form after its separation, and that the fire, or light, was extinguished by the projectile motion communicated by the stroke. Besides, may it not be supposed, that the sun, or

a burning star, moving with a rapidity equal to that of the planets, would soon be extinguished; and that this may be the reason why all the luminous, or burning stars, are fixed, and without motion; and why those called new stars, which have probably changed their stations, are frequently extinguished and disappear? To confirm this remark, comets, when in their perihelia, ought to be inflamed even to their centre; but they never become luminous stars; they only emit a burning vapour, a considerable portion of which they leave behind them in their course.

In a medium which has little resistance, I acknowledge, that fire may subsist, although the burning body be moved with great rapidity. It must likewise be acknowledged, that what I have said applies only to those stars which disappear for ever, not to those that appear and disappear at stated intervals, without changing their situations in the heavens. Of these Maupertuis, in his discourse on the figure of the stars, has given a most satisfactory account. But those which have appeared, and then vanished for ever, must unquestionably have been extinguished either by the quickness of their motion, or some other cause. There is not a single example of a luminous star revolving round another; and not one of the planets which revolve round the sun has any light in itself.

Farther, fire, in small masses, cannot subsist so long as in large ones. The planets would

burn a considerable time after they issued from the sun; but, at length, would extinguish for want of combustible matter. For the same reason, the sun itself will be extinguished; but at a period as much beyond that which extinguished the planets, as the quantity of matter in the sun exceeds that of the planets. However this may be, the separation of the planets from the sun, by the shock of a comet, appears sufficient to account for their extinction.

The earth and planets, when they issued from the sun, were totally composed of liquid fire; in which state they would continue no longer than the violence of the heat that kept them in fusion. But this heat would gradually decay from the moment they left the sun. During their fluid state, they necessarily assumed circular figures; and their diurnal motion would elevate their equators, and flatten their poles. I agree with M. Leibnitz*, that this figure corresponds so exactly with the laws of hydrostatics, that the earth and planets must necessarily have been once in a state of fluidity occasioned by fire; and, consequently, that the interior parts of the earth must be composed of vitrified matter, of which sand, free-stone, granite, and perhaps clay, are fragments, or scoriæ.

It is therefore extremely probable, that the planets were originally parts of the sun separated by a stroke which communicated to them a *projectile motion*; and that their different

* Vid. Act. Erud. Lips. an. 1692.

distances proceeded solely from the difference of their densities. To complete this theory, it only remains to account for the diurnal motion of the planets, and the origin of their satellites; which, instead of adding fresh difficulties, will tend greatly to confirm my hypothesis: for rotation, or what is called diurnal motion, entirely depends on the obliquity of the stroke; an oblique impulse on the surface of a body necessarily gives it a rotatory motion. If the body which receives the impulse be homogeneous, the rotatory motion will always be equal and uniform; but it will be unequal, if the body consist of heterogeneous parts, or of parts different in density. Hence we may conclude, that the matter of each planet is homogeneous, because the diurnal motion of each is uniformly performed in the same time; and this circumstance is an additional proof, that portions of different densities were originally separated from the sun.

But the obliquity of the stroke might be so great as to throw off small quantities of matter from the principal planet, which would necessarily move in the same direction. These parts, by mutual attraction, would reunite, according to their densities, at different distances from the planet, follow its course round the sun, and at the same time revolve about the body of the planet, nearly in the plane of its orbit. It is easy to perceive that the portions we mean are the satellites: thus the formation, position, and motion of the satellites correspond, in the most perfect manner, with our theory; for they all

move in the same direction, and in concentric circles round their principal planets, and nearly in the plane of their orbits. All these common effects, depending on an impulsive force, must have proceeded from a common cause, which was a projectile force communicated to them by the same oblique stroke. This account of the motion and formation of the satellites will be strongly supported, if the other circumstances and phænomena attending them be duly weighed. Those planets which are furnished with satellites move quickest round their axes. The revolution of the earth is quicker than that of Mars, in the proportion nearly of 24 to 15; the earth has a satellite, and Mars has none; Jupiter, whose diurnal motion is 500 or 600 times more rapid than that of the earth, has four satellites; and it is extremely probable, that Saturn, who has five* satellites and a ring, revolves much more quickly than Jupiter.

We may even conjecture, with some probability, that the plane of the equator of Saturn's ring is nearly the same with that of the planet; for, supposing, according to the preceding theory, the obliquity of the impulse which put Saturn in motion to have been very great, his diurnal motion would at first be in proportion to the excess of the centrifugal force above that of gravity, and, of course, a considerable quantity of matter would be thrown off from his equatorial

* Seven satellites, two having been added to the number, by the discoveries of Dr. Herschell, *viz.* the sixth in August, 1787, and the seventh in September, 1788. W.

regions, and necessarily assume the figure of a ring, the plane of which would be nearly the same with that of his own equator. This quantity of matter detached from the equatorial regions of Saturn, must have flattened the equator of that planet; which is the reason why, notwithstanding the rapidity with which we have supposed him to revolve round his axis, the diameters of Saturn are not so unequal as those of Jupiter, which differ from each other more than an eleventh part.

Though this theory of the formation of the planets and their satellites appears to be extremely probable; yet, as every man has his own standard of estimating probabilities of this nature, and as this standard varies according to the different capacities of combining analogies more or less remote, I pretend not to convince those who are unwilling to believe. I have offered these ideas to the public, not only because I thought them rational, and calculated to unravel a subject upon which, however important, nothing has hitherto been written; but because the impulsive motion of the planets gives rise to numberless phænomena in the universe, which admit not of an explanation by gravity alone. To those who may be disposed to deny the possibility of my theory, I would propose the following queries:

1. Is it not natnral to imagine, that a moving body has received its motion from the impulse of some other body?

2. When several bodies move in the same

direction, is it not exceedingly probable, that they received this direction from a single stroke, or, at least, from strokes every way similar?

3. When several bodies in motion have not only the same direction, but are placed in the same plane, is it not more natural to think that they received this direction and position from one impulse than from many?

4. Is it not probable, that a body put in motion by impulse, should receive it in an oblique direction; and, consequently, that it should be forced to move round its axis with a rapidity proportioned to the obliquity of the stroke? If these queries be not unreasonable, the theory of which we have given a sketch will no longer have the appearance of absurdity.

Let us now proceed to a more interesting object; let us examine the figure of the earth, upon which so many inquiries and observations have been made. As it appears, from the equality of the earth's diurnal motion, and the uniformity in the inclination of its axis, that it is composed of homogeneous parts, which mutually attract each other in proportion to their quantities of matter; if its impulsive motion had been communicated in a direction perpendicular to its surface, it would necessarily have assumed the figure of a perfect sphere: but, having been struck obliquely, it moved round its axis at the instant it received its figure; and, from the combination of the projectile force and that of attraction, there resulted a spheroid

figure, more elevated at the equator than at the poles; because the centrifugal force, arising from the diurnal rotation of the earth, must diminish the action of gravity, or that power which makes all the parts tend to the centre. Thus the earth, being composed of homogeneous parts, and having been endowed with a rotatory motion, must necessarily have assumed a spheroidal figure, the two axes of which differ from each other by a 230th part. To show that this is the real figure of the earth, we need not have recourse to hypotheses; it is capable of the clearest demonstration. The laws of gravitation are well known: that bodies attract each other directly as their quantities of matter, and inversely as the squares of their distances, admits not of a doubt. It can as little be doubted, that the total action of any body is composed of all the particular actions of its parts.

The parts of bodies are all mutually attracted in the above proportion; and all these attractions, when the body has no rotation, necessarily produce a sphere, and a spheroid, when the body is endowed with a rotatory motion. This spheroid is more or less flattened at the poles in proportion to the quickness of the diurnal motion; and the earth, in consequence of the celerity of its rotation, and the mutual attraction of its parts, has assumed the figure of a spheroid, of which the two axes are to one another as 229 to 230.

Thus the earth, at the time of its formation, from the original constitution and homogeneity

of its parts, and independent of every hypothesis derived from the direction of gravity, took the figure of a spheroid; and, from the known laws of mechanics, its equatorial diameter was necessarily elevated about six leagues and a half more than its poles.

I shall dwell the longer on this article, because there are some geometers, who, from a system of philosophy they have adopted, and from a supposed direction of gravity, still imagine that the figure of the earth depends upon theory. The first thing to be demonstrated is the mutual attraction of the parts of matter; and the second, the homogeneity of the terrestrial globe. When these two facts are clearly proved, there will be no occasion to have recourse to any theory derived from the direction of gravity; because the earth's figure, in this case, must necessarily be as Newton determined it; and all the other figures assigned to it, in consequence of vortexes, and other hypotheses, can have no existence.

It will not be doubted, even by the most incredulous, that the planets are retained in their orbits by the power of gravity. The satellites of Saturn gravitate towards that planet; those of Jupiter towards Jupiter; the moon gravitates towards the earth; and Saturn, Jupiter, Mars, *the earth, Venus, and Mercury, gravitate towards the sun. In the same manner, Saturn,* Jupiter, and the earth, gravitate towards their respective satellites, and the sun gravitates towards the whole planets. Gravitation is there-

fore a general law, by which the whole planetary system is mutually affected; for action cannot exist without re-action. This mutual attraction of the planets is the law which regulates all their motions; and its existence is demonstrated by its effects.* When Saturn and Jupiter are in conjunction, their mutual attraction produces an irregularity in their motion round the sun. The earth and the moon also mutually attract each other; but the irregularities in the moon's motion proceed principally from the attraction of the sun; and hence the sun, the earth, and the moon, mutually act upon each other. Now, the reciprocal attraction of the planets, when the distances are equal, is proportioned to their quantities of matter; and the same power of gravity, which makes heavy bodies fall to the earth, and which extends as far as the moon, is likewise in proportion to the quantity of matter: the total gravity of a planet, therefore, is composed of the gravity of all its parts: hence all the parts of matter, whether in the earth or planets, mutually attract each other; and, of course, the rotation of the earth round its axis must necessarily have bestowed on it the figure of a spheroid, the axes of which are as 229 to 230. But the direction of gravity must be perpendicular to the earth's surface; and, consequently, unless *the general and mutual attraction of the parts of matter be denied, no hypothesis derived from the direction of gravity can have any solid foundation.* But this mutual attraction, as we have seen, is demonstrated by actual observation;

and the experiments made by pendulums prove its universal extension. No hypothesis, therefore, founded on the direction of gravity, can be admitted, without contradicting both reason and experience.

Let us now examine whether the parts composing the terrestrial globe be homogeneous. I acknowledge, that, if the globe be supposed to consist of parts differing in density, the direction of gravity would be different from that we have assigned, and that the earth's figure would vary according to the different suppositions which might be made concerning the direction of gravity. But, why make suppositions of this kind? Why, for example, do we suppose the parts near the centre to be more dense than those more distant from it? Are not all the particles which compose the globe united by their mutual attraction? Every particle, therefore, is a centre; and there is no reason to believe that the parts which surround the centre are denser than those which surround any other point. Besides, if any considerable part of the earth were more dense than another, the axis of rotation would approach nearer that part, and create an inequality in the diurnal revolution of the globe: it would produce an inequality in the apparent motion of the fixed stars; they would appear to move more quickly or slowly in the zenith or horizon, according as we happened to be situated on the heavy or light parts of the earth; and the axis of the globe, not passing through its centre of gravity, would make a perceptible change in its

position. But nothing of this kind ever takes place. On the contrary, the diurnal revolution of the earth is equal and uniform. At every point of the earth's surface, the stars appear to move with the same quickness; and, if there be any nutation in its axis, it is too inconsiderable to attract observation. Hence it may be concluded, that all the parts of the globe are at least nearly homogeneous.

If the earth were hollow, the crust of which, for example, exceeded not three leagues in thickness, it would give rise to the following phænomena. 1. The mountains would bear so great a proportion to the total thickness of the crust, that vast irregularities in the earth's motion would be occasioned by the attraction of the moon and of the sun: when the moon was in the meridian of the more elevated parts, as the Cordeliers, her attraction upon the whole globe would be much greater than when she was in the meridian of the lower parts. 2. The comparative attraction of the mountains would be greatly increased; and the experiments made on Mount Chimboraco, in Peru, would have given more degrees in the deviation of the plumb-line than they actually gave seconds. 3. The weight of bodies would be greater on the tops of mountains than in the plains; and men would find themselves more weighty, and would walk with more difficulty, in high than in low grounds. These observations, and many others which might be made, should convince us, that the interior parts of the earth are not hollow, but that

they are composed of matter of a considerable density.

If, on the other hand, the earth, at the depth of two or three leagues, consisted of matter much denser than that we are acquainted with, upon descending even into ordinary pits, we should find ourselves considerably heavier; and the motion of pendulums would there be more accelerated than they actually are when brought down from a hill to a plain. Hence we may presume that the interior parts of the earth consist of matter nearly similar to that on its surface. Of this, we will be still farther convinced, if we consider that the earth, at the time of its original formation, when it assumed its present spheroidal figure, was in a state of fusion, and, consequently, that all its parts were homogeneous, and nearly of equal density. The matter on the surface, though originally the same with that of the interior parts, has, in the revolutions of time, undergone many changes from external causes; and to these are to be ascribed the production of materials so different in their densities. But it ought to be remarked, that the densest bodies, as gold, and other metals, are most rarely to be met with; and, consequently, that the greatest quantity of materials, at the surface, have suffered little alteration with regard to density. The most common materials, indeed, as sand and clay, differ so little in density, that we may conjecture, with much probability, the internal parts of the earth to consist of a vitrified matter, the density of which is

nearly equal to that of sand; and, consequently, that the whole globe may be considered as one homogeneous mass.

But, it may be said, that, though the earth were composed of concentric beds, of different densities, the equality of its diurnal motion, and the uniform inclination of its axis, would remain equally undisturbed, as upon the supposition of its consisting wholly of homogeneous matter. This I allow; but I demand, at the same time, whether there be any reason for believing that these beds of different densities really exist? Whether this method of solving difficulties be not an attempt to adjust the works of nature to our own imaginations? And whether suppositions, neither founded on observation nor analogy, ought to find admittance into physical reasoning?

Hence it is apparent, that the earth received its spheroidal figure in consequence of its diurnal motion and the mutual attraction of its parts; that this figure necessarily resulted from the globe's being in a liquid state; that, according to the laws of gravity and of a centrifugal force, it could not possibly assume any other figure; that, at the moment of its formation, the difference between its two diameters was, as at present, equal to a 230th part; and, of course, that all other hypotheses, which make this difference greater or less, are mere fictions, and deserve no attention.

Perhaps it may be objected, that, if this theory be well founded, and if the proportion of the

axes of the two diameters be as 229 to 230, how came the mathematicians sent to Lapland and Peru to concur in making it as 174 to 175? Why should such a difference subsist between practice and theory? And, is it not more reasonable to give the preference to actual measurement, especially when executed by the ablest mathematicians in Europe *, and furnished with all the necessary apparatus?

To this I reply, that I mean not to combat the observations made at the equator, and near the poles; that I doubt not of their exactness; and that the earth may actually be elevated a 175th part more at the equator than at the poles. Still, however, I maintain my theory; and I perceive clearly how it may be reconciled to practice. The difference between the two conclusions is about four leagues in the two axes. The equatorial regions are found to have an elevation of two leagues more than they ought to have by the theory. This height of two leagues corresponds exactly with the greatest inequalities which have been produced on the surface of the globe by the motion of the sea and the action of fluids. Here some illustration is necessary. At the time of the earth's formation, in consequence of the mutual attraction of its parts, and of its centrifugal force, it must have assumed a spheroidal figure, with its axes different by a 230th part. This would be the real figure of the earth while it remained in a state of lique-

* M. de Maupertuis, Figure de la Terre.

faction. But, after cooling for some time, the rarified vapours, like those in the tail or atmosphere of a comet, would condense, and fall on the surface in the form of air and water; and, when these waters begin to be agitated by a flux and reflux, sand, and other bodies, would be gradually transported from the poles towards the equatorial parts. This operation, when continued for some time, would necessarily sink the poles, and elevate the equator in the same proportion. The surface of the earth being likewise exposed to the winds, to the action of the air and of the sun; all these causes would concur with the tides in furrowing the earth, in scooping out valleys, in elevating the mountains, and in producing other superficial irregularities, none of which, perhaps, exceed a league in thickness, even at the equator. This inequality of two leagues may be supposed to be the greatest that can take place on the surface; for the highest mountains exceed not a league in height; and the most profound parts of the ocean, it is probable, are not above a league in depth. Thus my theory perfectly coincides with practice. The earth's equator could not, at first, be elevated more than six leagues and a half above the poles; but the changes produced on the surface might give it a still greater elevation. Natural history wonderfully supports this opinion; for, in the preceding discourse, we have proved, that, from the tides and other motions of the waters, have proceeded mountains, and all the other inequalities on the surface of the globe;

and that, at great depths, as well as upon the greatest heights, bones, shells, and other relics of sea and land animals, have been discovered.

From what has been observed, it may be conjectured, that, in order to find primitive earth, and substances which have never been removed from their original stations, we must dig in countries near the poles, where the bed of unmoved earth will be thinner than in southern climates.

In fine, if the measurement by which the figure of the earth was determined be strictly scrutinized, we shall find that it is not altogether free from hypothetical reasoning: for it proceeded on the supposition that the earth was a regular curve: but, as the earth is liable to considerable and constant changes from a thousand causes, it is impossible that it could have retained any perfectly regular figure; and hence, agreeable to our theory, and the opinion of Newton, the poles might originally be only flattened a 230th part. Besides, though we have the exact length of a degree at the equator and polar circle, yet we have not the exact length of a degree in France; and the measures of M. Picard have never been confirmed. It may be added, that the diminution and increase in the motion of the pendulum agree not with the conclusions drawn from measurement; and that, on the contrary, they correspond very nearly with the theory of Newton. These circumstances tend farther to convince us, that the poles are not depressed above a 230th part; and that, if there

be any difference, it can proceed from nothing but the inequalities produced on the surface by the waters, and other external causes. But these inequalities are by no means so regular as to justify any hypothesis, which supposes the meridians to be ellipses, or any other perfect curves. Hence it appears, that, though many degrees should be successively measured in different regions, we cannot, by that alone, ascertain the exact depression of the poles, nor determine how much it exceeds or falls short of a 230th part.

May we not likewise conjecture, that, if the inclination of the earth's axis has been changed, this effect could not be produced but by the changes on the surface, since all the other parts are homogeneous; that this variation is, of course, too small to be perceived by astronomers; and that, if the earth be not disturbed by a comet, or some other external cause, its axis will for ever preserve its present and original inclination?

Not to omit any conjecture that seems reasonable, may we not suppose, that, as the mountains and other inequalities on the surface of the earth, have originated from the action of the tides, those which we perceive in the moon have been produced by a similar cause? The mountains of the moon are indeed higher than those of the earth; but her tides are likewise stronger; because the earth, the size of which is much larger, raises the tides of the moon with a superior force. This effect would be greatly augmented, if the moon, like the earth, had a

quick diurnal motion. But, as the moon uniformly presents the same face to the earth, the tides are raised only in proportion to the motion occasioned by her librations, which alternately expose to our view a small segment of her other hemisphere. This cause, however, must produce tides very different from those of our seas; and their effects will, of course, be much less considerable, than if the moon had possessed a diurnal revolution round her axis, equally quick as the rotation of the earth.

I should compose a volume equal to that of Burnet or Whiston, were I to extend the ideas presented by the above theory; and were I, in imitation of the last-mentioned author, to clothe them in a geometrical dress, I might add considerably to their importance. But I have always thought, that hypotheses, however probable, deserve not to be treated so pompously. It is apt to give them the air of quackery and imposition.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE II.

Of the System of Whiston *.

THIS author begins his theory with a dissertation on the creation of the world. He alleges that the account given of it by Moses is not properly understood; and that, in inquiries of this kind, men, contenting themselves with the most evident and superficial views, give too little of their attention to nature, reason, and philosophy. The common notions, he observes, concerning the six days' work, are false; and the description of Moses is not an exact or philosophic account of the creation and origin of the universe, but only an historical narrative of the formation of the terrestrial globe. The earth, in his estimation, formerly existed in chaos, and, at the time mentioned by Moses, it only received a form,

* See a new Theory of the Earth by Will. Whiston, London, 1708.

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situation, and consistence, necessary for the habitation of mankind. I shall not give a detail of Whiston's proofs, nor enter upon a formal refutation of them, but content myself with a short view of his theory, which will show it to be contrary to the scriptures, and, of course, that his proofs must be false. Besides, he treats this matter more like a polemical divine than a philosopher.

Leaving these false principles, he proceeds to some ingenious notions, which, though singular, will not, to those who are influenced by the enthusiasm of system, appear to be destitute of probability. He tells us, that the ancient chaos, from which the earth originated, was the atmosphere of a comet; that the annual motion of the earth began when it received its new form; but that its diurnal motion commenced not till the fall of Adam; that the ecliptic cut the tropic of Cancer in a point precisely opposite to Paradise, which was situated on the north-west frontier of Assyria; that, before the deluge, the year began at the autumnal equinox, and that the orbits of the earth and planets were then perfect circles; that the deluge commenced on the 18th of November, in the year of the Julian period 2365, or 2349 before Christ; that, previous to the deluge, the solar and lunar year were the same, and consisted exactly of 360 days; that a comet, descending in the plane of the ecliptic to its perihelion, on the very day that the deluge began, made a near

approach to the earth; that there is a great heat in the bowels of the earth, which is constantly expanding from the centre to the circumference; that the figure of the earth resembles an egg; that the mountains are the lightest parts of the globe, &c. He then attributes to the deluge all the changes the earth has undergone, blindly adopts Woodward's theory, uses indiscriminately all that author's remarks on the present state of the earth; but assumes more the air of an original, when he treats of its future condition. The earth, says Mr. Whiston, will be consumed by fire; and its destruction will be preceded by earthquakes, thunder, and hideous meteors; the sun and moon will assume a dreadful aspect; the heavens will seem to fall; and the whole earth will be in flames. But, after the fire shall have devoured every impurity of this globe, and vitrified and rendered it transparent as the purest crystal, the saints and spirits of the blessed shall take possession of it, and there remain till the general judgment.

This hypothesis appears, at first view, to be extravagant and fantastical. But the author has managed his ideas with such dexterity, and placed them in so strong a light, that they no longer have the air of absolute chimeras. He has adorned his subject with much science and ingenuity: and it is astonishing, that, from such a medley of strange notions, he should have been able to compose a system so plausible. But it is not to the vulgar that it

has this brilliant appearance; the learned are more easily deceived by the glare of erudition and the force of new ideas. Mr. Whiston was a celebrated astronomer. Accustomed to contemplate the heavens, to measure the motions of the stars, and to consider the great phænomena of nature, he could never imagine that this grain of sand, which we inhabit, occupied more the attention of its Creator than the universe, which contains, in the vast regions of space, millions of other suns and other worlds. He alleges, that Moses has not given us the history of the first creation of this globe, but only a detail of those circumstances which attended its receiving a form fit for the habitation of men, when the Almighty transformed it from the state of a comet to that of a planet. Comets, owing to the eccentricity of their orbits, are subject to dreadful vicissitudes: sometimes, like that of 1680, they are a thousand times hotter than melted iron, and sometimes a thousand times colder than ice: they cannot, therefore, furnish habitation to any creatures of which we can form a conception; or rather, they are altogether uninhabitable.

The planets, on the contrary, are tranquil bodies; their distances from the sun vary but little; and their temperature continues so nearly the same, that it permits plants and animals to grow and to multiply.

In the beginning, says Mr. Whiston, God created the universe; but the earth was then an uninhabitable comet, and subject to such alter-

nate extremes of cold and heat, that its matter, being sometimes liquified and sometimes frozen, was in the form of chaos, or an abyss, surrounded with utter darkness: *and darkness covered the face of the deep.* This chaos was the atmosphere of the comet, a body composed of heterogeneous materials, having its centre occupied with a globular, solid, hot nucleus, of about 2,000 leagues in diameter, round which was an extensive mass of a thick fluid, mixed with heterogeneous and undigested materials, like the chaos of the ancients, *rudis indigestaque moles.* This great atmosphere contained few dry, solid, or earthy particles, and still less of water or air; but it was amply filled with thick and heavy fluids, mixed, agitated, and jumbled together in the utmost confusion. Such was the condition of the earth when six days old: but, next day, that is, on the first day of the creation, when the eccentric orbit of the comet was changed into an ellipse, nearly circular, every thing assumed its proper place; the different materials arranged themselves according to their specific gravities; the heavy fluids sunk down, and left to the earthy, watery, and aërial substances, the superior regions. These also descended in the order of their gravities; first the earth, then the water, and, lastly, the air. In this manner, the immense volume of chaos was reduced to a moderate sphere, the centre of which is a solid body, that still retains the heat it received from the sun, when formerly the nucleus of a comet.

This heat may easily last 6,000 years, since the comet 1680 would require 50,000 before it cooled. Round the solid and burning nucleus, at the centre of the earth, is placed the heavy fluid which descended first, and formed the great abyss, upon *which the earth floats like a cork on quicksilver. But* as *the* earthy parts were originally mixed with a great body of water, they, in descending, drove before them a part of this water, which was confined there when the earth consolidated, and formed a stratum concentric with the heavy fluid that surrounds the nucleus. Thus, the great abyss is composed of two concentric circles, the interior being a heavy fluid, and the superior water, upon which last the earth is immediately founded. From this admirable arrangement, produced by the atmosphere of a comet, are to be deduced the theory of the earth, and an explication of all its phænomena!

After the atmosphere of the comet had been freed from the solid and earthy particles, a pure air only remained, through which the rays of the sun instantly penetrated, and produced light: *Let there be light; and there was light.* The vast columns or beds of which the earth is composed, being formed with so much precipitation, is the reason why they differ so much in density; the heavier sunk deeper into the abyss than the lighter, and, of course, gave rise to mountains and valleys; these inequalities, before the deluge, were differently situated from what they are at present. Instead of that vast

valley which contains the ocean, many small caverns were dispersed over the globe, each of which contained a part of the waters. The mountains were then at greater distances, and formed not large chains. But the earth was a thousand times more fertile, and contained a thousand times more inhabitants; and the life of man, and of the other animals, was ten times longer. All these effects were produced by the superior heat of the central fire, which gave birth to a greater number of plants and animals, and, at the same time, bestowed on them a degree of vigour that enabled them to exist long, and to multiply abundantly. But this heat had a miserable effect upon the dispositions of men and other animals: it augmented the passions, robbed man of his innocence, and diminished the sagacity of the brute creation. All creatures, except the fishes, who inhabited a colder element, felt the influence of the central heat, became vicious, and merited death. This universal death was accordingly inflicted, on Wednesday the 28th day of November, by a dreadful deluge, which lasted forty days and forty nights, and was occasioned by the tail of a comet meeting with the earth, in returning from its perihelion.

The tail of a comet is the lightest part of its atmosphere. It is a transparent and subtile vapour, raised by the heat of the sun from the body of the comet. This vapour, which is composed of aërial and watery particles extremely rarified, follows the comet in its descent

to its perihelion, and goes before the comet in its ascent, its situation being always opposite to the sun, as if it had an affection for the shade, and wished to avoid the scorching rays of the sun. This column of vapour is often of an immense extent; and its length always increases in proportion as the comet approaches nearer the sun. Now, as many comets descend below the annual orbit of the earth, it is not surprising that the earth should sometimes be involved in this vapour. This dreadful event happened at the time of the deluge. The tail of a comet, in two hours, will discharge a quantity of water equal to that contained in the whole ocean. In fine, this tail is what Moses calls the cataracts of heaven: *and the cataracts of heaven were opened*. The globe of the earth, when it meets with a comet's tail, must necessarily, in its passage through this body of vapour, appropriate part of its materials. Every thing that comes within the sphere of the earth's attraction must fall upon it, and must fall in the form of vapour, since the tail itself principally consists of that element. In this manner, rain may come from the heavens in such torrents, as to produce an universal deluge, and to surmount the tops of the highest mountains.

Our author, however, unwilling to go beyond the letter of the sacred writings, does not ascribe the deluge to this rain alone, which he has chosen to bring from so great a distance. He takes advantage of water wherever he can find it: the great abyss, as we have seen, contains a

considerable quantity. The earth, in its approach towards the comet, would feel the force of its attraction; the waters in the great abyss would be so agitated with a motion similar to that of the tides, as would necessarily break the shell or crust in many places, and make the water rush out upon the surface: *and the fountains of the abyss were opened.*

But how, it may be asked, was this vast collection of water, so liberally furnished by the great abyss, and by the comet's tail, afterwards disposed of? Our author is not embarrassed by this circumstance. As soon as the earth escaped from the comet, the flux and reflux of the great abyss necessarily ceased. From that moment the waters on the surface rushed down with violence by the same channels out of which they had issued. The great abyss swallowed up not only its own water, but all that had been deposited by the comet, which it was sufficiently enabled to contain; because, during its agitation, and when it broke the crust, it had greatly enlarged its dimensions, by pushing the earth farther from it on all sides. It was at this time, likewise, that the earth, which was formerly a sphere, assumed its elliptical figure. This effect was produced by the centrifugal force occasioned by the diurnal motion of the earth, and by the attraction of the comet; for the earth, when passing through the tail of the comet, was so situated, that its equatorial parts were nearest that star; and, of course, the power of the comet's attraction, concurring with the earth's centri-

fugal force, elevated the equatorial regions with the greater facility, because the crust was broken in an infinite number of places, and because the flux and reflux of the abyss pushed more violently against the equator than any where else.

This is the history Mr. Whiston gives of the creation, of the causes of the universal deluge, of the longevity of the Antedeluvians, and of the figure of the earth. All these difficult subjects seem to have given our author very little trouble. But he appears to be greatly puzzled concerning Noah's ark. In that dreadful confusion, produced by the conjunction of the tail of a comet, and by the waters of the great abyss, and in that horrible period, when not only the elements of this globe were confounded, but when the heavens concurred with the bowels of the earth in producing new elements to increase the chaos, how is it to be imagined that the ark could float tranquilly, with its numerous and valuable cargo, upon the surface of the waves? Here our author struggles hard, in order to account for the preservation of the ark. But, as his reasoning upon this subject appears to be inconclusive, ill imagined, and heterodox, I shall only observe, how hard it is for a man, who had explained objects so great and surprising, without having recourse to a supernatural power, to be stopped in his career by a trifling circumstance. But he chooses to risk drowning himself along with the ark, rather than to ascribe the preservation of this precious vessel to the interposition of the Almighty!

I shall only make a single remark upon this system, of which I have given a faithful abridgement. Whenever men are so presumptuous as to attempt a physical explanation of theological truths; whenever they allow themselves to interpret the sacred text by views purely human; whenever they reason concerning the will of the Deity, and the execution of his decrees; they must necessarily involve themselves in obscurity, and tumble into a chaos of confusion, like the author of this whimsical system, which, notwithstanding all its absurdities, has been received with great applause. Mr. Whiston neither doubted of the truth of the deluge, nor of the authenticity of the sacred writings, but, as physics and astronomy occupied his principal attention, he mistook passages of holy writ for physical facts, and for results of astronomical observations; and so strangely jumbled divinity with human science, that he has given birth to the most extraordinary system that perhaps ever did or ever will appear.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE III.

*Of Burnet's Theory**.

MR. BURNET is the first author who discovered enlarged views of the present subject, and who treated of it in a systematic manner. He was a man of genius and of taste: his work acquired great reputation, and was of course, criticised by many of the learned, and, among others, by Mr. Keill, who, scrutinizing the subject as a geometer, demonstrated the errors of Burnet's theory in a treatise entitled, *An Examination of the Theory of the Earth.* Mr. Keill likewise refuted the system of Whiston; but he treated the latter in a manner very different from the former. He even appears, in many particulars, to adopt the opinions of Whiston; and considers the notion, that the deluge was

* Thomas Burnet. Telluris theoria sacra, orbis nostri originem et mutationes generales, quas aut jam subiit, aut olim subiturus est, complectens. Londini, 1681.

occasioned by the tail of a comet as exceedingly probable. But, to return to Burnet: his book is written with elegance. He knows how to paint the grandest images and the most magnificent scenes. His plan is elevated; but, being defective in proper materials, he often fails in the execution. His reasonings and his proofs are feeble; but the boldness with which he writes makes the reader lose sight of all his imperfections.

He begins with alleging, that the earth, before the deluge, was very different from what it is now. It was at first, says he, a fluid mass, composed of matters of every species, and of all kinds of figures, the heaviest of which descended to the centre, and formed a hard and solid body. The waters took their station round this body; and all lighter fluids rose above the water. Thus, between the coat of air, and that of water, a coat of oily matter was interposed. But, as the air was then full of impurities, and contained great quantities of earthy particles, these gradually subsided upon the coat or stratum of oil, and formed a crust composed of earth and oil: this crust was the first habitable part of the earth, and the first abode of man and other animals. The land thus formed was light, fat, and adapted to cherish the tenderness of the original germs. The surface of the earth was level and uniform, without mountains, seas, or other inequalities. But it remained in this state about sixteen centuries only; for the heat of the sun

gradually drying the crust, produced, at first, superficial fissures or cracks only; but, in process of time, these fissures penetrated deeper, and increased so much in their dimensions, that, at last, they entirely perforated the crust. In an instant, the whole earth split in pieces, and fell into the great abyss of waters which it formerly surrounded. This wonderful event was the universal deluge.

But all these masses of earth, in falling into the abyss, carried along with them vast quantities of air, and they dashed against each other, and accumulated and divided so irregularly, that great cavities filled with air were left between them. The waters gradually opened passages into these cavities, and, in proportion as the cavities were filled with the water, the surface of the earth began to discover itself in the most elevated places; and, at last, the waters appeared no where but in those extensive valleys which contain the ocean. Thus our ocean is a part of the ancient abyss; the rest of it remains in the internal cavities, with which the sea has still a communication. Islands and sea rocks are the small fragments, and continents are the large masses of the ancient crust. As both the rupture and fall of this crust were effected in a sudden and confused manner, it is not surprising that the surface of the present earth should be full of mountains, gulfs, plains, and irregularities of every kind.

This specimen is sufficient to give an idea of

Burnet's system. It is an elegant romance, a book which may be read for amusement, but cannot convey any instruction. The author was ignorant of the chief phænomena of the earth, and a man of no observation. He has drawn every thing from imagination, which often acts both against truth and reason.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE IV.

*Of the System of Woodward**.

OF this author it may be said, that he wanted to build an immense edifice upon a foundation less firm than sand, and to construct a world with dust; for, he asserts that the earth at the time of the deluge suffered a total dissolution. In perusing his book, the first idea which presents itself is, that this dissolution was effected by the waters of the great abyss. He alleges, that, at the command of God, the abyss suddenly opened, and diffused such an enormous quantity of water on the surface, as was sufficient to cover the tops of the highest mountains; and that God suspended the law of cohesion, which instantly reduced every solid substance into a powder, &c. He did not consider, that, by these suppositions, he added to the miracle of the universal deluge

* An Essay towards the Natural History of the Earth, by John Woodward.

many other miracles, or, at least, physical impossibilities, which accord neither with the scriptures, nor with the principles of mathematics and of natural philosophy. But as this author has the merit of collecting many important observations, and as he knew better than any former writer the materials of which the globe is composed, his system, though ill conceived and worse arranged, has seduced, by the lustre of a few striking facts, many weak men into a belief of his general conclusions.

We shall now give a short view of his theory, by which we will be enabled to do justice to the merit of the author, and put the reader in a condition to judge of the futility of his system, and of the falsehood of some of his remarks. Mr. Woodward informs us, that he recognised with his own eyes all the materials of which the earth in England is composed, from the surface to the greatest depths that had been dug; that they were all disposed in beds, or strata; and that, in many of these beds, there are shells and other productions of the sea. He then adds, that he was assured by his friends and correspondents, that in all the other countries of the world, the earth was composed of the same materials; and that shells are found, not only in the plains, and in some particular parts, but on the highest mountains, in the deepest pits, and in an infinite number of different places. He observed, that the beds were all horizontal, and placed over each other, like matters transported by the waters, and deposited in the form of sediment.

These general remarks, which are founded in truth, are followed with some particular observations, by which he demonstrates, that the fossil shells incorporated with the strata are real sea shells, and not peculiar minerals, or *lusus naturæ*, &c.

To these observations, though partly made before him, he has added others of a more suspicious nature. He asserts, that the materials of the different strata are arranged according to their specific gravities. This assertion is not consistent with truth: for we every day see solid rocks placed above clay, sand, pit coal, bitumen, and other comparatively light bodies. If, indeed, it were uniformly found, through the whole earth, that the upper stratum was bitumen, followed successively by strata of chalk, marl, clay, sand, stone, marble, and metals; it would, in that case, be probable that all those materials had been precipitated at once: and this our author affirms with confidence, though the most superficial observer needs only his eyes to convince him, that heavy strata are often found above light ones; and, consequently, that these sediments could not be deposited at the same time, but must have been transported and deposited by the ocean at successive periods. As this is the foundation of Woodward's system, and is manifestly false, we shall follow him no farther than to show how an erroneous principle produces false relations and bad conclusions.

All the strata which compose the earth, says our author, from the tops of the highest moun-

tains to the deepest mines, are placed according to their respective specific gravities. Hence, he concludes, the whole must have been in a state of dissolution, and precipitated at the same time. But at what time, in what menstruum, was it dissolved? In the water, says Mr. Woodward, and at the time of the deluge. But there is not water enough on the globe to produce this effect; for there is more earth than water; and the bottom of the sea itself is earth. Very well, he replies: but there is enough of water in the central parts of the earth; and nothing more was wanting than to bestow on it the power of dissolving every terrestrial substance, except sea shells; to find a proper method of making the waters return to the abyss; and to make all this correspond with the history of the deluge. Behold a system, of which the author could not prevail on himself to form a doubt; for, when it was objected to him, that water could not dissolve water, rocks, and metals, especially in forty days, the time of the waters remaining on the earth; he replied simply, that the event, however, did happen. When it was demanded of him, how the waters of the abyss could dissolve the whole earth, and yet preserve the shells? He answered, that he never proved that this water was a dissolvent; but that, from facts, it was clear that the earth had been dissolved, and that the shells were preserved. Lastly, when it was demonstrated to him, that his system was useless, as it was neither supported by reason nor by facts, he said, we had only to suppose that,

at the time of the deluge, the laws of gravity and of cohesion were suddenly stopped, and, upon this supposition, the dissolution of the ancient world admitted of an easy explanation. But, it was observed to him, if the force of cohesion was suspended, why were not the shells dissolved along with the rest? Here he gave a harangue on the organization of shells and of animal bones, tending to prove that their texture was fibrous, and different from that of minerals; that their cohesion was likewise different; and that, after all, we have only to suppose that the powers of gravity and of cohesion did not entirely cease, but that they were diminished to such a degree, as enabled them to dissolve the parts of minerals, but not those of animals. I shall conclude with remarking, that our author's philosophy was not equal to his talent for observation; it is therefore unnecessary to give a formal refutation of absurd notions, especially when they proceed upon conjectures which are contrary both to the laws of probability and of mechanics.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE V.

Examination of some other Systems.

THE three hypotheses formerly animadverted upon have many things in common: they all agree in this, that, at the time of the deluge, both the external and internal form of the earth was changed. But none of these theorists considered that the earth, before the deluge, was inhabited by the same species of men and animals; and, consequently, that it must have been nearly the same, both in figure and structure, as it is at present. We are informed by the sacred writings, that, before the deluge, there were rivers, seas, mountains, and forests; that most of these mountains and rivers remained nearly in their former situation; the Tigris and Euphrates, for example, ran through Paradise; that the Armenian mountain on which the ark rested, was, at the deluge, one of the highest mountains of the earth, as it is at this day; and that the same plants and the same animals, which inhabited the

earth before the deluge, continue still to exist; for we are told of the serpent, of the crow, and of the pigeon that carried the olive-branch into the ark. Tournefort indeed alleges, that there are no olives within 400 leagues of Mount Araret, and affects to be witty on this head. It is, however, indisputable, that there were olives in the neighbourhood of this mountain at the time of the deluge; for Moses assures us of the fact in the most express manner. Besides, it is not surprising, that, in the course of 4,000 years, the olives should be extirpated in these provinces, and multiplied in others. It is, therefore, contrary both to scripture and reason, that these authors have supposed the earth, before the deluge, to have been totally different from what it is now; and this opposition between their hypotheses and the sacred writings, as well as sound philosophy, is sufficient to discredit their systems, although they should correspond with some phænomena *. Burnet, who wrote first, gives neither facts nor observations in support of his system. Woodward's book is only a short essay, in which he promises much more than he was able to perform; it is only a project, without any degree of execution. He makes use of two general remarks: 1. That the earth is every where composed of materials which had formerly been in a state of fluidity, and which had been deposited by the waters in horizontal beds. 2. That, in the bowels of many parts of the

* See Voyage du Levant, vol. ii. p. 336.

earth, there are an infinite number of sea bodies. To account for these facts, he has recourse to the universal deluge; or rather, he appears to employ these as proofs of the deluge. But, like Burnet, he falls into evident contradictions; for it is absurd to suppose, with these authors, that, before the deluge, there were no mountains, since we are expressly told, that the waters rose fifteen cubits above the tops of the highest mountains. On the other hand, it is not said that the waters destroyed or dissolved the mountains. In place of this extraordinary dissolution, the mountains remained firm in their original situations, and the ark rested upon the one which was first deserted by the waters. Besides, it is impossible to imagine, that, during the short time the deluge continued, the waters could dissolve the mountains, and the whole fabric of the earth. Is it not absurd to suppose, that, in the space of forty days, the hardest rocks and minerals were dissolved by simple water? Is it not a manifest contradiction to admit this total dissolution, and yet to maintain that shells, bones, and other productions of the sea, were able to resist a menstruum to which the most solid materials had yielded? Upon the whole, I cannot hesitate in pronouncing, that Woodward, though furnished with excellent facts and observations, has produced but a weak and inconsistent theory.

Whiston, who wrote last, has greatly improved upon the other two; and, though he has given loose reins to his imagination, it cannot be said that he falls into contradiction. He

advances many things which are incredible; but they are neither absolutely nor apparently impossible. As we are ignorant of what materials the centre of the earth is composed, he thinks himself entitled to suppose it a solid nucleus, surrounded with a ring of heavy fluid matter, and then follows a ring of water, upon which the external crust is supported. In this ring of water, the different parts of the crust sunk more or less in proportion to their gravities, and gave rise to mountains and inequalities on the surface of the earth. But our astronomer here commits a blunder in mechanics. He considered not, that the earth, on this supposition, must have formed one uniform arch; and, consequently, that it could not be supported by the water, and far less could any part of this arch sink deeper than another. If this be excepted, I doubt whether he has fallen into any other physical blunder: he has, however, committed many errors both in metaphysics and theology. In fine, it cannot be denied absolutely, that the earth, in meeting with the tail of a comet, would be deluged, especially if it be allowed to the author, that the tails of comets contain watery vapours. Neither is it absolutely impossible, that the tail of a comet, in returning from its perihelion, should burn the earth, if we suppose, with Mr. Whiston, that the comet passed very near the sun's body. The same observations may be made upon the rest of his system. But though his notions be not absolutely impossible, when taken separately, they are so exceedingly improbable,

that the whole assemblage may be regarded as exceeding the bounds of human credulity.

These three are not the only books which have been written upon the theory of the earth. In 1729, M. Bourguet published, along with his *Philosophical Letters on the Formation of Salts*, &c. a memoir, in which he gives a specimen of a system which he had projected; but the execution of it was prevented by the death of the author. It must be acknowledged, that no man was more industrious and acute in making observations, and in collecting facts. To him we are indebted for remarking the correspondence between the angles of mountains, which is the chief key to the theory of the earth. He arranges the materials he had collected in the best order. But, with all these advantages, it is probable, that he would not have succeeded in giving a physical history of the changes which have happened in the earth; and he appears not to have discovered the causes of those effects which he relates. To be convinced of this remark, we have only to take a view of the propositions he deduces from those phænomena which must have been the foundation of his theory. He says, that the earth was formed at once, and not successively; that its figure and disposition demonstrate that it was formerly in a fluid state; that the present condition of the earth is very different from what it was some ages after its first formation; that the matter of the globe was originally more soft than after its surface was changed; that the condensation of its solid parts

diminished gradually with its velocity; so that, after a certain number of revolutions round its own axis, and round the sun, its original structure was suddenly dissolved; that this happened at the vernal equinox; that the sea shells insinuated themselves into the dissolved matters; that the earth, after this dissolution, assumed its present form; and that, as soon as the fire or heat operated upon it, its consumption gradually began, and, at some future period, it will be blown up with a dreadful explosion, accompanied with a general conflagration, which will augment the atmosphere, and diminish the diameter of the globe; and then the earth, in place of strata of sand or clay, will consist only of beds of calcined materials, and mountains composed of amalgams of different metals.

This is a sufficient view of the system which M. Bourguet designed to compose. To guess at the past, and to predict the future, nearly in the same manner as others have guessed and predicted, requires but a small effort of genius. This author had more erudition than sound and general ideas. He appears not to have had the capacity of forming enlarged views, or of comprehending the chain of causes and effects.

In the Leipsic Transactions, the celebrated Leibnitz published a sketch of an opposite system, under the title of Protogæa. The earth, according to Bourguet and others, was to be consumed by fire. But Leibnitz maintains, that it originated from fire, and that it has undergone innumerable changes and revolutions. At

the time that Moses tells us the light was divided from the darkness, the greatest part of the earth was in flames. The planets, as well as the earth, were originally fixed and luminous stars. After burning for many ages, he alleges, that they were extinguished from a deficiency of combustible matter, and that they became opaque bodies. The fire, by melting the matter, produced a vitrified crust; and the basis of all terrestrial bodies is glass, of which sand and gravel are only the fragments. The other species of earth resulted from a mixture of sand with water and fixed salts; and, when the crust had cooled, the moist particles, which had been elevated in the form of vapour, fell down, and formed the ocean. These waters at first covered the whole surface, and even overtopped the highest mountains. In the estimation of this author, the shells, and other spoils of the ocean, which every where abound, are indelible proofs that the earth was formerly covered with the sea; and the great quantity of fixed salts, of sand, and of other melted and calcined matters shut up in the bowels of the earth, demonstrate, that the conflagration had been general, and that it had preceded the existence of the ocean. These ideas, though destitute of evidence, are elevated, and bear conspicuous marks of ingenuity. The thoughts have a connexion, the hypotheses are not impossible, and the consequences which might be drawn from them are not contradictory. But the great defect of this theory is, that it applies not to the present state of the

earth. It only explains what passed in ages so remote, that few vestiges remain; a man may, therefore, affirm what he pleases, and what he says will be accompanied with more or less probability, in proportion to the extent of his talents. To maintain, with Whiston, that the earth was originally a comet, or with Leibnitz, that it was a sun, is to assert what is equally possible or impossible; it would, therefore, be ridiculous to investigate either by the laws of probability. The instantaneous creation of the world destroys the notion of the globe's being covered with the ocean, and of that being the reason why sea shells are so much diffused through different parts of the earth; for, if that had been the case, it must of necessity be allowed, that shells, and other productions of the ocean, which are still found in the bowels of the earth, were created long prior to man, and other land animals. Now, independent of scripture authority, is it not reasonable to think that the origin of all kinds of animals and vegetables is equally ancient?

M. Scheutzer, in a dissertation addressed to the Academy of Sciences in 1708, attributes, like Woodward, the change, or rather new creation of the globe, to the deluge. To account for the formation of mountains, he tells us, that God, when he ordered the waters to return to their subterraneous abodes, broke, with his Almighty hand, many of the horizontal strata, and elevated them above the surface of the earth, which was originally level. The whole disser-

tation was composed with a view to support this ridiculous notion. As it was necessary that these eminences should be of a solid consistence, M. Scheutzer remarks, that God only raised them from places which abounded in stones. Hence, says he, those countries, like Switzerland, which are very stoney, are likewise mountainous; and those, like Flanders, Holland, Hungary, and Poland, which are mostly composed of sand and clay to great depths, have few or no mountains *.

This author, like Woodward, blends physics and theology; and, though he has made some good observations, the systematic part of his work is weaker and more puerile than that of any of his predecessors. He has even descended to declamation, and absurd pleasantries. The reader, if he desires to see them, may consult his *Piscium Querelæ*, &c., not to mention his *Physica Sacra*, consisting of several volumes in folio, a weak performance, fitter for the amusement of children than the instruction of men.

Steno, and some others, have attributed the origin of mountains, and other inequalities upon the surface of the earth, to particular inundations, earthquakes, &c. But the effects of these secondary causes could produce nothing but slight changes. These causes may co-operate with the first cause, namely, the tides, and the motion of the sea from east to west. Be-

* Vid. Hist. de l'Acad. 1708, p. 32.

sides, Steno has given no theory, nor even any general facts, upon this subject*.

Ray alleges, that all mountains have been produced by earthquakes, and has written a treatise to prove the point. When we come to the article of volcanos, we shall examine the foundation of this opinion.

We cannot omit observing here, that Burnet, Whiston, Woodward, and most other authors, have fallen into an error which deserves to be rectified. They uniformly regard the deluge as an effect within the compass of natural causes, although the scripture represents it as an immediate operation of the Deity. It is beyond the power of any natural cause to produce on the surface of the earth a quantity of water sufficient to cover the highest mountains: and, although a cause could be imagined adequate to this effect, it would still be impossible to find another cause capable of making the waters disappear. Granting that Whiston's waters proceeded from the tail of a comet, we deny that any of them could issue from the abyss, or that the whole could return into it; for the abyss, according to him, was so environed and pressed on all sides by the terrestrial crust, that it was impossible the comet's attraction could produce the least motion in the fluid it contained, far less any motion resembling the tides: hence, not a single drop could either proceed from, or enter into, the great

† Vide Dissert. de Solido intra Solidum nato, &c.

abyss. Unless, therefore, it is supposed, that the waters which fell from the comet were annihilated by a miracle, they would for ever have remained on the surface, and covered the tops of the highest mountains. The impossibility of explaining any effect by natural causes, is the most essential character of a miracle. Our authors have made several vain efforts to account for the deluge. Their errors in physics, and in the secondary causes they employ, prove the truth of the fact, as related in scripture, and demonstrate, that the universal deluge could not be accomplished by any other cause than the will of the Deity.

Besides, it is apparent, that it was not at one time, nor by the sudden effect of a deluge, that the sea left uncovered those continents which we inhabit; it is certain, from the authority of scripture, that the terrestrial Paradise was in Asia, and that Asia was inhabited before the deluge; consequently, the waters, at that period, covered not this large portion of the globe. The earth before the deluge, was nearly the same as now. This enormous quantity of water, poured out by Divine justice upon guilty men, destroyed every living creature; but it produced no change on the surface of the earth; it destroyed not even the plants; for the pigeon returned to the ark with an *olive branch* in her bill.

Why then should we suppose, with many naturalists, that the waters of the deluge totally changed the surface of the globe, even to the

depth of two thousand feet? Why imagine that the deluge transported those shells, which are found at the depth of seven or eight hundred feet, immersed in rocks and in marble? Why refer to this event the formation of hills and mountains? And how is it possible to imagine, that the waters of the deluge transported banks of shells of 100 leagues in length! I perceive not how they can persist in this opinion, unless they admit a double miracle, one to create water, and another to transport shells. But as the first only is supported by holy writ, I see no reason for making the second an article of faith.

On the other hand, if the waters of the deluge had retired suddenly, they would have carried off such immense quantities of mud and soil, as would have rendered the land unfit for culture, till many ages after this inundation. In the inundation which happened in Greece, the country that was covered remained barren for three centuries*. Thus the deluge ought to be regarded as a supernatural mode of chastising the wickedness of men, not as an effect proceeding from any natural cause. The universal deluge was a miracle, both in its cause and in its effects. It appears from the sacred text, that the sole design of the deluge was the destruction of men and other animals, and that it changed not in any manner the surface of the earth; for, after the retreat of the waters, the mountains and even the trees, kept their for-

* Vide Acta erudit. Lips. 1691, p. 100.

mer stations, and the land was suited for the culture of vines and other fruits of the earth. It might be asked, if the earth was dissolved in the waters, or, if the waters were so much agitated as to transport the shells of India into Europe, how the fishes, which entered not into the ark, were preserved?

The notion that the shells were transported and left upon the land by the deluge, is the general opinion, or rather superstition, of naturalists. Woodward, Scheutzer, and others, call petrified shells the remains of the deluge; they regard them as medals or monuments left us by God of this dreadful catastrophe, that the memorial of it might never be effaced among men. Lastly, they have embraced this hypothesis with so blind a veneration, that their only anxiety is to reconcile it with holy writ; and, in place of deriving any light from observation and experience, they wrap themselves up in the dark clouds of physical theology, the obscurity and littleness of which derogate from the simplicity and dignity of religion, and present to the sceptic nothing but a ridiculous medley of human conceits and divine truths. To attempt an explanation of the universal deluge and of its physical causes; to pretend to give a detail of what passed during this great revolution; to conjecture what effects have resulted from it; to add facts to the sacred writings, and to draw consequences from these interpolations: is not this a presumptuous desire of scanning the power of the Almighty? The natural wonders wrought

by his beneficent hand, in a uniform and regular manner, are altogether incomprehensible; his extraordinary operations, or his miracles, ought, therefore, to impress us with an awful astonishment, and a silent respect.

It may still be urged, that, as the universal deluge is an established fact, is it not lawful to reason upon its consequences? True. But you must commence with acknowledging, that the deluge could not possibly be the effect of any physical cause; you must regard it as an immediate operation of the Deity; you must content yourself with what is recorded in scripture; and you must, above all, avoid blending bad philosophy with the purity of divine truth. After taking these precautions, which a respect for the counsels of the Almighty requires, what remains for examination upon the subject of the deluge? Do the sacred writings tell us that the mountains were formed by the deluge? They tell us the reverse. Do they inform us that the agitation of the waters was so great, as to raise the shells from the bottom of the ocean, and to disperse them over the face of the earth? No: the ark moved gently on the surface of the waters. Do they tell us, that the earth suffered a total dissolution? By no means. The narration of the sacred historian is simple and true; that of naturalists is complicated and fabulous.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE VI.

Geography.

THE surface of the earth is not, like that of Jupiter, divided into alternate bands or belts, parallel to the equator. On the contrary, it is divided, from one pole to the other, into two belts of earth, and two of sea. The first and principal belt is the Ancient Continent, the greatest length of which is a line commencing at the most eastern point of the north of Tartary, and extending from thence to the neighbourhood of the gulf of Linchidolin, where the Russians fish whales; from thence to Tobolski; from Tobolski to the Caspian Sea; from the Caspian Sea to Mecca; from Mecca to the western part of the country inhabited by the Galli in Africa; from thence to Monoemuci, or Monomotapa; and, lastly, to the Cape of Good Hope.

This line is about 3,600 leagues in length, and is never interrupted but by the Caspian and the Red Seas, the breadth of which is inconsiderable, and ought not to be regarded, especially as, like our seasons, the whole surface of the globe is divided into four parts only.

This greatest length of the Old Continent lies in a diagonal line; for, if measured by a meridian, it will appear, that, from the northernmost point of Lapland to the Cape of Good Hope, exceeds not 2,500 leagues; and that this line, though shorter, meets with greater interruptions from the Baltic and Mediterranean. With regard to all other lines which could be drawn under the same meridians in the Old Continent, they must still be shorter than those we have mentioned. For example, from the most southern point of the Island of Ceylon to the northernmost coast of Nova Zembla, is 1,800 leagues. In the same manner, if the Continent be measured by lines parallel to the equator, its greatest length, without much interruption by seas, will stretch from Trefana, on the west coast of Africa, to Ninpo, on the east coast of China, which is about 2,800 leagues. Another line may begin near Brest, and extend to the coast of Chinese Tartary, which will be nearly 2,300 leagues. From Bergen in Norway, to the coast of Kamtschatka, is only 1,800 leagues. All these lines are much shorter than the first. Hence the greatest length of the Old Continent extends from the eastern point of Tartary to the Cape

of Good Hope, and is about 3,600 leagues *.— See plate i.

This line may be considered as the middle of the Ancient Continent; for, in measuring the surface on each side of it, I find, that on the left, there are 2,471,092¾ square leagues; and, on the right, there are 2,469,687, which is an equality so astonishing, as to render it extremely probable that this line, which is the longest, at the same time really divides the contents of the Ancient Continent.

Hence the Old Continent consists of about 4,940,780 square leagues, which is a fifth part of the surface of the globe, and may be regarded as a large belt of earth, with an inclination to the equator of about thirty degrees.

The New Continent is another belt of earth, the greatest length of which may be taken from the mouth of the river Plata to the lake of the Assiniboils. This line passes from the mouth of the river Plata to Lake Caracara; from thence to Mataguais, Pocona, Zongo, Mariana, Morua, St. Fe, and Carthagena; then it passes through the gulf of Mexico to Jamaica and Cuba; from thence along the peninsula of Florida, through Apalache, Chicachas; and from thence to St. Louis, Fort le Sueur, and terminates in the country bordering on Lake Assi-

* By leagues I mean those used in the environs of Paris, which are 2,000 or 2,100 fathoms long, and about 27 of them make a degree.

niboils, the extent of which is unknown.—See plate ii.

This line is interrupted only by the Gulf of Mexico (which may be considered as a Mediterranean sea), is about 2,500 leagues in length, and divides the New Continent nearly into two equal parts, that on the left containing 1,069,286$\frac{5}{6}$ leagues square, and that on the right 1,070,926$\frac{1}{12}$. It is the middle of the belt of land called the New Continent, and is likewise inclined to the equator about 30 degrees, but in an opposite direction; for that of the Old Continent extends from the north-east to the south-west; but that of the New Continent from north-west to south-east. The superficial contents of the Old and New Continents are about 7,080,993 square leagues, not near a third part of the surface of the globe, which contains 25,000,000 square leagues.

Of these lines, which divide the Continents into two equal parts, it may be remarked, that they both terminate at the same degrees of north and south latitude; and that the two Continents make mutual advances, or projections, exactly opposite to each other, namely, those on the African coast, from the Canary Isles to Guiney; and those of America, from Guiana to the mouth of the Rio-Janeiro.

It is, therefore, apparent, that the most ancient lands on the globe are those which extend from 200 to 250 leagues on each side of the two lines above described. Agreeable to this idea, which

is founded on the observations already made, we find that, in the Old Continent, the most ancient countries of Africa are those which stretch from the Cape of Good Hope to the Red Sea and Egypt, and are about 500 leagues broad; and, consequently, that the whole western coast of Africa, from Guiney to the Straits of Gibraltar, are new lands. In the same manner, if we trace this line through Asia, and include an equal breadth, we shall find, that the most ancient countries are, the two Arabias, Persia, Georgia, Turcomania, a part of Independent Tartary, Circassia, part of Muscovy, &c.; and, of course, that Europe, and perhaps also China, and the eastern part of Tartary, are comparatively new countries.

In the New Continent, we shall likewise find, that Terra Magellanica, the eastern part of Brasil, of the country of the Amazons, of Guiana, and of Canada, are new lands, when compared with Tucuman, Peru, Terra Firma, the islands in the Gulf of Mexico, Florida, the Missisippi, and Mexico. To these observations may be added two remarkable facts. The Old and New Continents are nearly opposite to each other. The Old Continent extends farther north of the equator than south; but the New, farther south than north. The centre of the Old Continent lies in the 16th or 18th degree of north latitude; and the centre of the New Continent lies in the 16th or 18th degree of south latitude, as if they were intended to counterbalance each other.

There is another singular analogy between the *two Continents,* though it appears to be chiefly the effect of accident. Both Continents might be divided into two portions, which would be surrounded on all sides by the sea, except the two small isthmuses of Suez and Panama.

These general observations on the division of the globe are the result of an attentive survey. We shall not, upon this foundation, erect hypotheses, or indulge in reasonings, which might lead to false conclusions. But, as the division of the globe has not hitherto been considered under this point of view, I shall hazard a few remarks. It is not a little singular, that the longest line which can be drawn upon the two Continents should, at the same time, divide them into two equal parts. It is not less remarkable, that these two lines should commence and terminate at the same degrees of latitude, and have the same inclination to the equator. These relations may lead to general conclusions, of which we are still ignorant. We shall afterwards examine, in detail, the inequalities in the figure of the two Continents, and shall here only remark, that the most ancient countries should be found in the neighbourhood of the above lines, and should, at the same time, have the highest elevation; and that the more recent lands should be most remote from these lines, and likewise lie lower. Agreeable to this idea, the newest countries in America should be the land of the Amazons, Guiana, and Canada. In examining the

map of these countries, we perceive that they are every where divided by numberless lakes and rivers, which is a still stronger indication of their recent origin. On the other hand, the regions of Tucuman, Peru, and Mexico, are high mountains, and situated near the line that divides the Continent; circumstances which seem to prove the superior antiquity of these countries. Africa is also extremely mountainous, and at the same time very ancient. In this part of the globe, Egypt, Barbary, and the western coast, as far as Senegal, can only be considered as new lands. Asia is perhaps the most ancient of all countries, especially Arabia, Persia, and Tartary. But the inequalities of this great division of the globe, as well as those of Europe, shall be treated of in a separate article. We shall only remark, in general, that Europe is a new country, as appears from those universal traditions concerning migrations of different nations, and the origin of arts and sciences. It is not long since Europe was full of marshes and forests. But, in countries anciently inhabited, there are few woods, lakes, or marshes, but a great deal of heath and shrubs, and many high mountains, with dry and barren tops; for men destroy woods, drain marshes and lakes, and, in process of time, give an appearance to the face of the earth totally different from that of uninhabited or newly peopled countries.

In this article of general geography, I have endeavoured to reach that degree of exactness

which subjects of such a nature require; yet a few slight errors have escaped me. For example,

1. I have not used the names adopted or given by the French to several parts of America. I have uniformly followed the British globes made by Senex, of two feet diameter, from which my charts were exactly copied. The British are more just than the French, with regard to countries they discover, or through which they travel. They preserve the original name of each country, or that which was bestowed on it by the first discoverers. We, on the contrary, often give French names to the countries we visit, which is the cause of that obscurity in the geographical nomenclature of our language. But, as the lines which traverse the two Continents in their greatest length are well marked, in my charts, by the two extreme points, and several other intermediate ones, whose names are generally adopted, no essential ambiguity can arise from this circumstance.

2. I have likewise neglected to give the calculation of the surface of the two Continents, because it is easily made on a large globe. But, as many persons have expressed a desire to see this calculation, I here subjoin that which M. Robert de Vaugondi transmitted to me at the time*.

* Calculation of our Continent by geometrical leagues square.

14 d.	14 d.	14 d.	14 d.	14 d.	
5 E	8 D	$10\frac{1}{2}$ C	$12\frac{1}{2}$ B	$13\frac{1}{2}$ A	14 d.
78,750	80,937	100,625	113,750	$120,312\frac{1}{2}$	

From this calculation it appears, that, on the left of the line of partition, there are 2,471,092$\frac{3}{4}$ of square leagues, and 2,469,687 square leagues on the right of the same line; and consequently that

Calculation of the left half.		Calculation of the right half.	
A × 3 =	360,937$\frac{1}{2}$	A × 3 =	360,937$\frac{1}{2}$
A × 3$\frac{1}{2}$ =	421,093$\frac{3}{4}$	A × 1 =	120,312$\frac{1}{2}$
B × 3$\frac{1}{2}$ =	398,125	B × 1 =	113,750
B × 4 =	455,000	B × 4$\frac{1}{3}$ =	492,916$\frac{2}{3}$
C × 2 =	201,250	C × 1 =	100,625
C × 3 =	301,875	C × 4$\frac{1}{3}$ =	436,041$\frac{2}{3}$
D × 1 =	80,937$\frac{1}{2}$	D × 1 =	80,937$\frac{1}{2}$
D × 2 =	161,874	D × 4$\frac{1}{3}$ =	350,729
E × 1 =	78,750	E × 1 =	78,750
E × "$\frac{1}{7}$ =	11,250	E × 4$\frac{1}{4}$ =	334,687$\frac{1}{2}$
	2,471,092$\frac{3}{4}$		2,469,687

2,471,092$\frac{3}{4}$
2,469,687

Difference 1,405$\frac{3}{4}$

Which is scarcely a degree and a half square.

Calculation of the Continent of America according to the same measures.

Calculation of the left half.		Calculation of the right half.	
D × 2 =	161,965	D × 2$\frac{2}{3}$ =	215,833$\frac{1}{3}$
C × 2 =	201,250	C × 2$\frac{1}{4}$ =	225,406$\frac{1}{4}$
B × 2 =	227,500	A × "$\frac{1}{5}$ =	24,062$\frac{1}{2}$
A × "$\frac{1}{2}$ =	60,156$\frac{1}{4}$	A × 1$\frac{1}{5}$ =	144,375
A × "$\frac{2}{3}$ =	80,208$\frac{1}{3}$	B × 2 =	227,500
B × "$\frac{4}{5}$ =	91,000	C × 2$\frac{1}{6}$ =	218,020
C × 1$\frac{1}{4}$ =	125,801$\frac{1}{4}$	D × "$\frac{1}{5}$ =	15,750
D × 2 =	121,406		
	1,069,286$\frac{5}{6}$		1,070,926$\frac{1}{12}$

the Old Continent consists of about 4,940,780 square leagues, which is not one fifth part of the earth's surface.

In the same manner, the part on the left of the line of partition in the New Continent, contains 1,069,286$\frac{5}{8}$ square leagues, and that on the right of the same line consists of 1,070,926$\frac{1}{18}$; in all, about 2,140,213 square leagues; which makes not one half of the surface of the Old Continent. As both Continents contain but 7,080,993 square leagues, their superficies is not near one third of the total surface of the globe, which is about 26 millions of square leagues.

3. I ought to have mentioned the small difference of inclination that subsists between the two lines by which I divided the two Continents. I contented myself with saying, that they were both inclined to the equator, in opposite sides, about 30 degrees, which is not the precise fact; for that of the Old Continent is a little more than 30 degrees, and that of the New a little less. If I had given this explanation, I should have avoided the imputation of having drawn two lines of unequal lengths, under the same

	1,070,926$\frac{1}{18}$
	1,069,286$\frac{5}{8}$
Difference	1,639$\frac{1}{4}$

Which is scarcely a degree and one fifth square.

Superficies of the New Continent	2,140,213	
Superficies of the Old Continent	4,940,780	
Total - -	7,080,993	square leagues.

angle between two parallels; which would have proved, as an anonymous critic remarks *, that I am unacquainted with the elements of geometry.

4. I have neglected to distinguish Upper from Lower Egypt; insomuch that, in the two places where I have mentioned the country, there is an appearance of contradiction. In the first of those passages, Egypt seems to be ranked among the most ancient lands, while, in the second, it is reckoned among the most recent. I was wrong in not distinguishing, as I had elsewhere done, Upper Egypt, which is a very ancient land, from Lower Egypt, which is a very new territory.

With regard to the figure of Continents, I shall transcribe a passage from the ingenious author of the Philosophical and Political History of the two Indies.

"It is now thought to be certain," he remarks, "that the surface of the New Continent is not one half of that of the Old. Besides, in their figure there are some striking analogies.—They seem to form two immense bands of earth, which arise from the Arctic pole, terminate in the South, and separated on the East and West by the ocean that invests them. Independent of the structure of these two bands, and of the counterpoise or symmetry which takes place in their figure; it is apparent, that their equilibrium depends not on their position; it is the fluctuation of the sea which produces the stability of

* Lettres à un Americain.

the earth. To fix the globe on its base, it was necessary to have an element which, by floating continually around this planet, should counterbalance, by its weight, the other substances, and restore that equilibrium which the collision of the other elements might have disturbed. Water, by its fluidity and gravity, is well fitted to support that harmony and that balance of the different parts of the globe around its centre.

"If the waters which still moisten the bowels of the New Hemisphere had not deluged its surface, man would soon have cut down the woods, drained the marshes, and given consistence to a watery soil. — He would have opened vents to the winds, and confined the rivers within their banks; the climate, of course, would have already been changed. But an uncultivated and thinly inhabited hemisphere announces a recent land, while the waters which environ its coasts still creep silently through its veins."

On this subject I shall remark, that, although there is more water on the surface of America than on that of other countries, we ought not to conclude from this circumstance, that an internal sea is contained in the bowels of this new land. We should only infer from this number of lakes, marshes, and large rivers, that America has been peopled long after Asia, Africa, and Europe, where the quantity of stagnant waters is much less. Besides, a thousand other circumstances concur in showing, that the Continent of America, in general, ought to be regarded as new land,

in which Nature has not had time to acquire all her powers, nor to exhibit them by a numerous population.

A small portion of the globe only was known to the ancients. The whole of America, the Arctic Circle, Terra Australis and Magellanica, and a great part of the interior regions of Africa, were unknown to them. They knew not that the Torrid Zone was inhabited, although they had sailed round Africa. About 2,200 years ago, Neco King of Egypt furnished some vessels to the Phœnicians, who sailed down the Red Sea, doubled the Cape of Good Hope, and the third year after their departure they entered the Mediterranean by the Straits of Gibraltar *. The ancients, notwithstanding, were totally ignorant of the polarity of the loadstone, although they knew its power of attracting iron; they knew not the cause of the tides; and they were uncertain whether the ocean surrounded the globe. Some of them, indeed, suspected that it might be so; but these conjectures were so ill founded, that none of them ever dreamed of its being possible to circumnavigate the earth. Magellan, in the year 1519, was the first who attempted this great voyage; and he accomplished it in 1,124 days. Francis Drake, in the year 1577, was the second; and he performed it in 1,056 days. Thomas Cavendish set out upon this voyage in 1586, and finished it in 777 days.

* See Herodotus, lib. 4.

These celebrated navigators were the first who *gave a physical* demonstration of the sphericity and extent of the circumference of the earth. The ancients, though they travelled much, had no adequate idea of the extent of the globe. They were equally ignorant of the trade-winds, which are so useful in long voyages. Their limited knowledge in geography, therefore, should not surprise us, especially when it is considered, that, notwithstanding the advantages derived from the mathematical sciences, and from the discoveries of navigators, many points remain still undetermined, and vast regions are yet undiscovered. Of the countries in the neighbourhood of the south pole, we only know that they exist, and that they are separated from the other continents by the ocean *. Much, likewise, remains to be discovered concerning the lands near the north pole: and it is a subject of regret, that, for a century past, the ardour for discovering new countries has greatly abated. The nations of Europe seem, and perhaps they are right, more disposed to increase the value of those countries they have already discovered, than to acquire new territories.

The discovery, however, of the Southern Continent would be a grand object of curiosity, and might be attended with the greatest advantages.

* Captain Cooke, in his late voyage, has demonstrated, in the completest manner, that no continent exists near the south pole.

A few of its coasts have been recognized; but those navigators, who have attempted this discovery, have always been prevented from reaching land by large bodies of ice. The thick fogs which infest those seas form another obstacle. But, notwithstanding all these inconveniences, it is probable, that, by setting out from the Cape of Good Hope at different seasons, part of this new world might still be discovered.

Another method might, perhaps, be attended with more success. To avoid the fogs and the ice, the discovery might be attempted, by departing from Baldivia, or some other port on the coast of Chili, and traversing the South Sea under the 50th degree of south latitude. This navigation appears not to be hazardous; and it is probable that it would be attended with the discovery of new lands; for the regions about the south pole, still unknown, are so extensive, that they may be computed to be about a fourth part of the globe; and, consequently, may contain a country as large as the whole of Europe, Asia, and Africa.

To what I have said concerning the Terra Australis, I shall add, that within these few years, new attempts have been made to discover it, and that some points of it have been found after departing either from the Cape of Good Hope, or from the Isle of France; but that these new voyagers have uniformly met with thick fogs, snow, and ice, in the 46th or 47th degree of south latitude. After conversing with some of

these voyagers, and collecting all the information I could derive from other sources, I perceived that they all agreed with regard to this fact, and that they found ice in much lower latitudes than is to be met with in the northern hemisphere. They likewise uniformly met with fogs in the same latitudes where they found ice, though it was summer in these climates at the time the experiments were made. It is, therefore, extremely probable, that, below the 50th degree, it will be in vain to search for temperate countries in the southern hemisphere, where the freezing cold is much farther extended than in the northern. The thick fog is produced by the presence or neighbourhood of the ice. This fog consists of minute particles of snow, which are suspended in the air, and render it obscure: it often accompanies the great floating masses of ice, and reigns perpetually in frozen regions.

Besides, the British have lately sailed round New Holland as well as New Zealand. These southern countries are more extensive than the whole of Europe. New Zealand is divided into several islands; but New Holland ought rather to be regarded as a part of Asia, than as an island belonging to the Southern Continent; for New Holland is only separated from the land of the Papous, or New Guiney, by a narrow strait, and the whole Archipelago, which extends southward from the Philippine isles, as far as the country of Arnhem in New Holland, and toward the west

and south, as far as Sumatra and Java, appears to belong as much to the Continent of New Holland, as to the southern parts of Asia.

Captain Cook, who ought to be regarded as the greatest navigator of this age, and to whom we are indebted for an infinite number of new discoveries, has not only given a chart of the coasts of Zealand and New Holland, but has likewise explored an immense tract of the South Sea in the neighbourhood of America. He departed from the south point of America on the 30th of January 1769, and he traversed a great part of the ocean under the 60th degree, without discovering any land. From Captain Cook's chart we may perceive the great extent of sea which he explored; and his tract demonstrates, that, if any lands exist in this part of the globe, they must be far removed from the Continent of America; for New Zealand, which is situated between the 35th and 45th degrees, is very distant from America. But it is still to be hoped, that other navigators, following the tract of Captain Cook, will traverse the southern ocean under the 50th degree, and that they will discover whether these immense regions, which extend more than two thousand leagues, consist of land or of sea. However, I do not imagine that the southern regions, beyond the 50th degree, are so temperate that any advantage could be derived to us from the discovery of them.

While we remain ignorant of this part of the earth, we cannot determine the proportion the surface of the land bears to that of the ocean;

from what we do know, it appears that there is more sea than land.

To acquire an idea of the vast quantity of water in the ocean, we must suppose a medium depth, for example, that of 200 fathoms, or the sixth part of a league. Upon this supposition, there is as much water in the ocean as would be sufficient to cover the whole globe to the depth of 600 feet; or, if collected into one mass, it would form a globe of 60 leagues in diameter.

It is alleged by navigators, that the latitudes near the south pole are much colder than the same latitudes towards the north. But this opinion seems to have no foundation. It appears to have been adopted from the circumstance of ice appearing in latitudes where none is found in the northern seas. But this effect may be owing to some peculiar causes. After the month of April, there is no ice on this side of 67 or 68 degrees of north latitude; and the savages of Acadia and of Canada say, that if the ice be not melted in April, it indicates a cold and rainy summer. The year 1725 was distinguished by an almost perpetual rain; and, in April, the ice in the northern seas was not only not melted at the 67th degree, but, on the 15th of June, it was found in lat. 41 or 42*.

Great quantities of floating ice appear in the north seas, especially at considerable distances from land. They come from the Tartarean Sea, into that of Nova Zembla and other parts of the

* See l'Hist. de l'Acad. anneé 1727.

Frozen Ocean. I have been assured by people worthy of credit, that an English captain, called Manson, instead of searching for a passage to China between the northern lands, directed his course straight to the pole till he arrived within two degrees of it; and that, in this course, he found an open sea, and no ice; which is a clear proof that the ice is always formed near the land, and never in an extensive sea: for, though it should be supposed, contrary to probability, that the cold was so intense at the pole as to freeze the surface of the sea, it is still inconceivable how these enormous floating masses could be formed, without being attached to the land, from which they are again separated by the heat of the sun. Two vessels sent by the East India Company, in 1739, to discover land in the south seas, found islands of ice in lat. 47 or 48; but they were not very distant from the shore, which was in view, though the vessels could not make their landing good *. These islands of ice must have been detached from the lands in the neighbourhood of the south pole; and it may be conjectured that they follow the course of some large rivers in these unknown regions, in the same manner as the Oby, the Jemsca, and other great rivers that fall into the north seas, carry down masses of ice, which shut up, during the greatest part of the year, the straits of Waigat, and render the sea of Tartary, by this course, altogether inaccessible; while, beyond Nova Zem-

* *See on this subject a chart by M. Buache, 1739.*

bla, and near the pole, where there is little land and few rivers, ice is less frequent, and the sea more navigable. Hence, if any farther attempts be made to find a passage to China and Japan by the north seas, it will, perhaps, be necessary to keep at a distance from the land and the ice, to steer directly towards the pole, and to explore the most open seas, where unquestionably there is little or no ice: for it is well known, that salt water can take on a greater degree of cold, without freezing, than fresh water after it is congealed; consequently the excessive cold at the pole may render the sea colder than ice, without freezing its surface. Besides, at 80 or 82 degrees, the sea, though mixed with snow and fresh water, is never frozen, except near the coasts. From the united testimony of several navigators, it is apparent, that there is a passage from Europe to China by the north sea: the reason why it has so often been in vain attempted is obvious. Fear prevented the undertakers from keeping at a sufficient distance from the land, and from approaching the pole, which they probably imagined to be an immense rock.

William Barents, however, who, like many others, had run aground in his voyage, never doubted the existence of such a passage, or that, if he had kept farther from land, he would have found an open sea without ice. The Russian navigators sent by the Czar to reconnoitre the north sea, relate, that Nova Zembla is not an island, but a part of Tartary, and that, to the north of it, there is a free and open sea. A

Dutch voyager affirms, that whales are occasionally thrown upon the coasts of Corea and of Japan, with European harpoons sticking in their backs. Another Hollander alleges, that he had penetrated to the pole itself, and assures us, that it was as warm as at Amsterdam in summer. One Goulden, an Englishman, who had made above thirty voyages to Greenland, related to Charles II. that two Dutchmen, who sailed along with him, having been unsuccessful in fishing off the coast of the Isle of Edges, resolved to proceed northward; that, upon their return, fifteen days after, they told him, that they had been at the 89th degree of latitude, where they found no ice, but an open, deep sea, like that in the Bay of Biscay; and that they showed him the two ships' journals in support of what they advanced. In fine, it is related in the Philosophical Transactions, that two navigators, who engaged in the discovery of this passage, penetrated 300 leagues to the east of Nova Zembla; but, on their arrival, the East India Company, who thought they had an interest in preventing the discovery, allowed them not to return that way to Europe*. But the Dutch East India Company, who believed themselves interested in the discovery, having made unsuccessful attempts on the European side, tried to find it by the way of Japan; and they would probably have succeeded, if the Emperor of China had not prohibited all strangers from navigating on the

* See Collect. of Voyages to the North, p. 200.

coasts of the lands of Jesso. This passage, therefore, cannot be found but by steering directly to the pole beyond Spitzbergen, or rather by keeping the open sea between Nova Zembla and Spitzbergen, under the 79th degree of latitude. For the reasons already given, there is no occasion to dread ice, even under the pole itself; for there is no example of a large sea freezing at a great distance from land. The only sea that freezes totally is the Black Sea, which is narrow, contains little salt, and receives from the northern countries a number of rivers, and large islands of ice. If we may credit historians, this sea, in the time of the Emperor Copronymus, froze to the depth of 30 cubits. This may be an exaggeration: but that it freezes every winter is certain, while open seas, 1,000 leagues nearer the pole, never do. This fact can only be explained by the superior saltness, and the comparatively small quantity of ice which these seas receive.

Islands of ice, which have been regarded as invincible obstacles to navigation near the poles, prove only the existence of large rivers in the neighbourhood of the places where they appear. They also demonstrate the existence of vast continents, from which these rivers derive their sources; and, therefore, we ought not to be discouraged by their appearance: besides, very little reflection will convince us, that these heaps of ice must be confined to particular places; that it is impossible they should occupy the whole circle in which the Southern Continent is supposed to be

contained; and, therefore, if a different route were taken, we have reason to hope for success. From the description of New Holland, given by Dampier, and others, it is probable, that this part of Terra Australis, which is, perhaps, a part of the Southern Continent, is a country less ancient than what remains to be discovered. New Holland lies low; it has neither mountains nor rivers*; it is thinly inhabited, and the natives have no industry. All these circumstances induce us to think, that the savages of New Holland are similar to those of the Amazons, and of Paraguay, in America. In Peru and Mexico, which are the most elevated, and, of course, the most ancient countries of America, the manners of the inhabitants were polished; and they were divided into distinct nations, governed by sovereigns and by laws. Savages, on the contrary, are always found in low and new countries. Hence we may presume, that, in the elevated and interior parts of the Southern Continent, from which issue those large rivers that carry down heaps of ice to the sea, there are men united by the bonds of society.

The interior parts of Africa are nearly as little known to us as they were to the ancients. They

* We have no good reason to suppose that New Holland has neither mountains nor rivers; on the contrary, a chain of mountains is said to run north and south between fifty and sixty miles in land; but not easily accessible on account of numerous deep ravines: and, it is highly probable, that such an extensive country produces some considerable rivers, though we have not as yet discovered them. W.

had circumnavigated this immense peninsula; but they have neither left us charts nor descriptions of its coasts. Pliny tells us, that this voyage was performed in the days of Alexander the Great; that the wrecks of some Spanish ships were found in the Arabian sea; and that Hanno, the Carthaginian general, had sailed from Gades to the Arabian gulf, and had written a relation of the voyage. He farther informs us, that, in the days of Cornelius Nepos, one Eudoxus, who had been persecuted by King Lathurus, was obliged to fly; that he departed from the Arabic gulf, and arrived at Gades; and that, previous to this period, Spain carried on a trade by sea with Æthiopia *. But, these testimonies notwithstanding, we are of opinion, that the ancients never doubled the Cape of Good Hope: every man considered the voyage of the Portugueze to the East Indies as a new discovery. It will not be incurious to see the sentiments entertained of this subject in the ninth century. "In our days, a discovery has been made which was totally unknown to those who lived before us. No man believed, or could suspect, that the sea which reaches from the Indies to China, had any communication with the sea of Syria. But we have lately found, according to my information, in the Mediterranean, or sea of *Roum*, the wreck of an Arabian ship which had been staved to pieces by a tempest. Some of these pieces had been carried, by the wind and the waves,

* See Plin. Hist. Nat. tom. i. lib. 2.

into the sea of the Cozars; from thence round to the Mediterranean, and along that sea to the coast of Syria. This is a demonstration that the ocean surrounds China and Cila, the extremity of Turqueston, and the country of the Cozars, and that, at last, it enters by the Straits, and washes the borders of Syria. The evidence arises from the construction of the vessel; for there are no ships but those of Siraf whose planks are not nailed. But the vessel above mentioned had all her planks stitched together in a manner peculiar to the Arabians. But all vessels belonging to the Mediterranean, and the coast of Syria, have their timbers fastened with nails *."

I shall subjoin the remarks added by the translator of this ancient relation:

"Abuziel remarks, as a thing perfectly new, that a vessel had been carried from the Indian Sea, and thrown upon the coast of Syria. To find a passage for it into the Mediterranean, he supposes, that there is a great extent of sea beyond China which communicates with the sea of the Cozars, or of Muscovia. The sea beyond Cape Current was entirely unknown to the Arabians, on account of the extreme hazard of navigating it, and because the continent was inhabited by a people so barbarous, that it was impossible either to conquer them, or to civilize them by commerce. The Por-

* See Les anciennes Relationes des Voyages faits par Terre a la Chine, p. 53.

tugueze found not, from the Cape of Good Hope to Soffala, any Moors who had an established settlement, like those in all the maritime villages as far as China, which was the farthest place known to geographers. But they could not tell whether the Chinese Sea communicated with that of Barbary by the extremity of Africa; they only described it to the coast of Zinga or Caffraria. We cannot, therefore, hesitate in pronouncing, that the first discovery of the passage of this sea, by the Cape of Good Hope, was made by the Europeans under the command of Vasça de Gama, or, at least, a few years before he doubled that Cape, if we may credit some sea charts of an older date, where the Cape is marked under the name of *Fronteira da Africa*. Antony Galvan relates, upon the testimony of Francisco de Sousa Tavares, that, in 1528, the Infant Don Ferdinand showed him a similar chart from the monastery of Acoboca, dated 120 years before, copied, perhaps, from that said to be in the treasury of St Marc at Venice, on which the point of Africa is likewise delineated, according to the evidence of Ramusio," &c.

The ignorance of these ages concerning the navigation round Africa is not, perhaps, so singular as the silence of the editor of this ancient relation with regard to the passages in Herodotus, Pliny, &c., which we have quoted, and which proved that the ancients had sailed round Africa.

However this matter stands, the coasts of Africa are now well known. But all the attempts which have been made to penetrate into the interior parts, have not furnished us with exact accounts. It would be a great object to go far up the country, by means of the Senegal, or some other great river, and establish settlements. According to every appearance, we should there find a country as rich in precious metals as Peru or Brasil. It is well known, that the rivers of Africa abound in gold dust; and, as the country is very high and mountainous, and is, besides, situated under the equator, it unquestionably contains, as well as America, mines of the heaviest metals, and stones of the hardest and most compact texture.

The vast extent of north and east Tartary is but a late discovery. If the Russian charts be just, we know the whole coast of this part of Asia; and it appears, that, from the termination of east Tartary to North America, it is an extent not above 400 or 500 leagues. It has even been lately reduced to a much shorter space. In the Amsterdam Gazette of 24th January 1747, under the article Petersburgh, it is alleged, that M. Stolleravoit had discovered, beyond Kamtschatka, one of the North American isles, and that he had demonstrated that we might sail from Russia to America by a very short passage. The Jesuits and other missionaries also pretended to have known savages in Tartary, whom they had catechized in America, which supposes the

passage to be indeed very short *. Charlevoix would have us believe, that the Old and New Continents are united in the northern parts. He says, that some late voyages of the Japanese make it probable that the passage we have been mentioning is only a bay, beyond which we may pass, by land, from Asia to America. But this notion requires confirmation; for it has always been thought, that the continent of the north pole is probably separated from all other continents, as well as that of the south pole.

Astronomy and navigation have reached so high a pitch of perfection, that we may reasonably hope soon to have an exact knowledge of the whole surface of the globe. The ancients, who were ignorant of the mariner's compass, were able to discover a small part of it only. Some pretend that the Arabians invented this instrument, and that, by means of it, they carried on trade with India as far as China †. But this notion has always appeared to me to be destitute of foundation; for there is not in the Arabian, Turkish, or Persian languages, a word that signifies a mariner's compass: they use the Italian word *bossola*. Even at this moment, they can neither make compasses nor give polarity to the needle. They purchase these articles from the Europeans. Father Martini alleges, that the Chinese have been acquainted with the compass

* See Charlevoix, tom iii. p. 30.

† See l'Abregé de l'Hist. des. Sarazins de Bergeron, p. 119.

these 3,000 years *. If these facts be true, how should it happen that they have made so little use of this instrument? Why, in their voyage to Cochinchina, did they take a longer course than was necessary? Why did they always limit themselves to the same expeditions, the longest of which was to Java and Sumatra? And why did they not discover, before the Europeans, a vast variety of islands and of fertile countries in their own neighbourhood, if they possessed the art of navigating in the open seas? It was but a few years after the discovery of this wonderful quality of the loadstone, that the Portugueze doubled the Cape of Good Hope, and traversed the African and Indian oceans, and that Christopher Columbus sailed to America.

It was not difficult to conjecture, that immense regions existed in the western part of the globe; for, on computing what was known of it, namely, the distance from Spain to China, and attending to the revolution of the earth, or of the heavens, it was easy to perceive, that a greater extent lay to the west than what had been already discovered on the east. That the ancients found not the New World, was not owing to a deficiency in astronomical science, but solely to their ignorance of the compass. The passages of Plato and of Aristotle, which mention countries far beyond the Pillars of Hercules, seem to indicate that some mariners had been driven by a tempest on the coast of America, from which they had

* See Hist. Sinica, p. 106.

returned with infinite labour. But, supposing the ancients to have been thoroughly convinced, from the relations of voyagers, that such a continent existed, being ignorant of the compass, they could not possibly derive any advantage from such conviction.

I acknowledge, that it is not absolutely impossible for resolute men, with no other guide than the stars, to sail in open seas. The ancients were in possession of the Astrolabe. They might take their departure from France or Spain, and sail to the west by always keeping the polar star on their right hand; and, by frequent soundings, they might keep nearly in the same latitude. It was unquestionably by keeping the pole-star on their left, that the Carthaginians mentioned by Aristotle were enabled to return from those distant regions. But it will still be allowed, that a voyage of this kind must have been regarded as a rash and hazardous enterprise. We ought not, therefore, to be surprised, that the ancients never conceived such a project.

With regard to the invention of the mariner's compass, I have to add, that, from the testimony of Chinese authors, of which M. le Rouse and M. de Guignes have made an abridgment, it appears to be certain, that the polarity of the magnetic needle has been very anciently known to the inhabitants of China. The figure of these first compasses was that of a man, who turned upon a pivot, and whose right arm pointed to the south. The time of this invention, according to certain Chinese chronicles, was 1,115 years be-

fore the Christian æra, and, according to others, 2,700 *. But notwithstanding the antiquity of this discovery, it does not appear that the Chinese had ever derived from it the advantage of making long voyages.

Homer, in the Odyssey, tells us, that the Greeks employed the loadstone to direct their navigation when they went to besiege Troy; and this æra is nearly the same with that recorded in the Chinese Chronicle. Hence we can no longer doubt, that the direction of the loadstone toward the pole, and even the use of the mariner's compass in navigation, were known to the ancients at least 3,000 years ago.

Before the expedition of Columbus, the Azores, the Canaries, and Madeira, had been discovered. It had been remarked, that, when the west winds continued long to blow, the sea threw upon the coasts of these islands pieces of strange wood, canes of an unknown species, and even dead bodies, which, by several marks, were known to be neither Europeans nor Africans †.

Columbus himself remarked, that, on the west coasts, certain winds blew for some days, which he was persuaded proceeded from land. But, though he possessed all these advantages over the ancients, and likewise the compass, the difficulties to be encountered were so great, that nothing less than success could have justified the en-

* See l'Extrait des Annales de la China, par Mrs. Rouse and de Guignes.

† See Charlevoix, tom i. p. 66.

terprise. Suppose, for a moment, that the continent of America had been 1,000 or 1,500 leagues more distant, a circumstance which Columbus could not foresee, he never would have arrived, and perhaps this vast country might still have remained undiscovered. This conjecture receives additional force, when it is considered, that Columbus, though the ablest navigator of his age, was seized with terror and astonishment in his second voyage to the New World: as, in his first voyage, he found nothing but islands, he directed his course more to the south in quest of a continent; but found himself stopped by currents, the great extent of which, and their uniform opposition to his course, obliged him to direct his search more to the west. He imagined, that it was not currents which prevented him from advancing to the south, but that the sea was rising to the heavens, and that both perhaps touched each other in the southern parts: thus, in great undertakings, the most trifling difficulty may sometimes turn a man's brain, and extinguish his courage.

To what I said concerning the discovery of America, a critic of more judgment than the author of *Lettres à un Américain*, has accused me of doing a kind of injury to the memory of so great a man as Christopher Columbus. "It is confounding," he remarks, "Columbus with his sailors, to think that he could believe the sea rose toward the sky, and that they perhaps touched each other on the southern part of the globe." This criticism is extremely just. I ought

to have softened this fact, which I had extracted from some historical relation; for this great navigator, it is to be presumed, must have had very distinct notions concerning the figure of the earth, which he derived both from his own voyages, and from those of the Portugueze to the Cape of Good Hope and the East Indies. It is well known, however, that Columbus, when he arrived at the New Continent, thought himself at no great distance from the east coasts of Asia. As no man, at that period, had circumnavigated the world, he could not know its circumference, and did not imagine that the earth was so extensive as it has been demonstrated by later discoveries. Besides, it must be acknowledged, that this first navigator toward the west, could not fail to be astonished to find, that, when below the Antilles, it was impossible for him to gain the southern regions, and that he was continually forced back. This obstacle still subsists. We cannot, in any season, sail directly from the Antilles to Guiana; because the currents are extremely rapid, and constantly run from Guiana to those islands. Ships sail from Guiana to the Antilles in five or six days; but they require two months to return. In order to return, they are obliged to make a large circuit toward the Old Continent, from whence they direct their course toward the Terra Firma of South America. These rapid and perpetual currents from Guiana to the Antilles are so violent that they cannot be surmounted by the aid of the wind; and, as this

circumstance is unexampled in the Atlantic ocean, it is not surprising that Columbus, who, notwithstanding all the resources of his genius and knowledge in the art of navigation, could not advance toward the southern regions, should think that something of a very extraordinary nature existed in this place, and perhaps that there was a greater elevation in this part of the sea than in any other; for the currents from Guiana to the Antilles actually run with as much rapidity as if they descended from a height.

The motion of the following rivers may give rise to the currents from Cayenne to the Antilles.

1. The impetuous river of the Amazons, whose mouth is seventy leagues broad, and its direction more to the north than the south.

2. The river Ouassa is likewise rapid, has the same direction, and its mouth is nearly a league wide.

3. The Oyapok is still more rapid than the Ouassa, passes through a greater tract of land, and its mouth is nearly of the same dimension.

4. The Aprouak has nearly the same extent of course and of mouth as the Ouassa.

5. The river Kaw is less extensive both in its course and mouth; but though it issues from a Savannah about twenty-five or thirty leagues from the sea, it is extremely rapid.

6. The Oyak, which is a considerable river, divides into two branches at its mouth, and forms the island of Cayenne. This river, at the distance of twenty or twenty-five leagues, receives

another called Oraput; it is very impetuous, and derives its source from a mountain of rocks, from whence it descends in rapid torrents.

7. One branch of the Oyak runs, near its mouth, into the river of Cayenne; and these two rivers, when united, are more than a league broad; the other branch exceeds not half a league.

8. The river of Kourou, which is very rapid, and not above half a league wide at the mouth, without reckoning the Macousia, which, though it furnishes much water, comes from no great distance.

9. The Sinamari is an impetuous river; it comes from a great distance, and its bed is pretty narrow.

10. The river Maroni, though it be very rapid, comes from a great distance. Its mouth is more than a league broad, and, next to the Amazon, it discharges the greatest quantity of water. It gives rise to no islands; while the mouths of the Amazon and Oronoko are interspersed with a great number.

11. The rivers of Surinam, of Barbiché, of Essequebé, and some others, till we reach the Oronoko, which is a very large river.

By the accumulations of mud and of earth, brought down from the mountains by these rivers, it should appear, all the valleys of this vast continent have been formed; in the middle of the continent there are some mountains, most of which have formerly been volcanoes, and are

not sufficiently elevated to allow their summits to be covered with snow or ice.

Hence it is apparent, that the united force of all these rivers gives rise to that general current of the sea from Cayenne, or rather from the Amazon, to the Antilles; and that this general current extends, perhaps, above sixty leagues from the eastern coast of Guiana.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE VII.

Of the Formation of Strata, or Beds in the Earth.

WE have demonstrated, in the first article, that the earth, in consequence of the mutual attraction between the particles of matter, and of the centrifugal force that results from its diurnal revolution, must have assumed the figure of a spheroid, the two diameters of which differ about a 230th part; and that nothing but the changes made on the earth's surface, by the motions of the air and of the waters, could augment this difference, in the manner alleged by those who measured a degree under the equator, and another within the polar circle. This figure of the earth, which agrees so well with the laws of hydrostatics and with our theory, indicates that, at the time it assumed its figure, it was in a state of fluidity. We have also proved, that the pro-

jectile motion, and the motion of rotation, were impressed at the same time, and by the same impulse. It will more readily be admitted, that the earth was originally in a state of liquefaction, when it is considered, that the greatest part of the materials of which this globe is composed are either vitrifications, or vitrifiable by fire. The impossibility of rendering the earth fluid by the *operation of waters confirms this hypothesis; because there is infinitely more earth than water,* and the water is not able to dissolve sand, rocks, and hard minerals.

It is, therefore, evident, that the earth assumed its figure when in a fluid state: and, to pursue our theory, it is natural to think, that the earth, when it issued from the sun, had no other form but that of a torrent of melted and inflamed matter; that this torrent, by the mutual attraction of its parts, assumed a globular figure, which its diurnal motion changed into a spheroid; that, when the earth cooled, the vapours which were expanded like the tail of a comet, gradually condensed, fell down in the form of water upon the surface, depositing, at the same time, a slimy substance, mixed with sulphur and salts, part of which was carried, by the motion of the waters, into the perpendicular fissures of the strata, and produced metals, and the rest remained on the surface, and gave rise to the vegetable mould, which abounds, in different places, with more or less of animal and vegetable particles, whose organization is not obvious to the senses.

Thus the interior parts of the globe were originally composed of vitrified matter; and, I believe, they continue so at present. Above this vitrified matter were placed those bodies which the fire had reduced into the smallest particles, as sands, which are only portions of glass; and above these, pumice stones, and the scoriæ of melted matter, which gave rise to the different clays. The whole was covered with water to the depth of 500 or 600 feet *, which originated from the condensation of the vapours, when the earth began to cool. This water deposited a stratum of mud, mixed with all those matters that are capable of being sublimed or exhaled by fire; and the air was formed of the most subtile vapours, which, from their levity, rose above the water.

Such was the condition of the earth, when the tides, the winds, and the heat of the sun, began to introduce changes on its furnace. The diurnal motion of the earth, and that of the tides, elevated the waters in the equatorial regions, and necessarily transported thither great quantities of slime, clay, and sand, and, by thus

* This opinion, that the earth was entirely covered with water, corresponds with the sentiments of several ancient philosophers, and likewise with those of many of the fathers of the church. "In mundi primordio, aqua in omnem terram stagnabat," says St. John of Damascus, lib. 2. cap. 9. "Terra erat invisibilis, quia exundabat aqua et operiebat terram;" St. Ambrose, lib. 1. cap. 8. "Submersa tellus cum esset, faciem ejus, inundante aqua, non erat adspectabilis;" St. Basile, Hom. 2. See likewise St. Agustine, lib. i. cap 12.

elevating these parts of the earth, they perhaps sank those under the poles about two leagues, as was formerly remarked: for the waters would easily reduce into powder pumice-stones, and other spongy parts of the vitrified matter upon the surface, and, by this means, excavate some places, and elevate others, which, in time, would produce islands and continents, and all those inequalities on the surface, that are more considerable towards the equator than the poles. The highest mountains lie between the tropics, and the middle of the Temperate Zones, and the lowest from the polar circles towards the poles. Between the tropics are the Cordeliers, most of the mountains of Mexico and the Brazils, the Great and Lesser Atlas, the mountains of the Moon, &c. Besides, both the land and the sea have most inequalities between the tropics, as is evident from the incredible number of islands peculiar to these regions.

However independent of my general theory this hypothesis, concerning the original state of the globe, may be, I have chosen to refer to it in this article, with a view to show the connexion and possibility of the system endeavoured to be established in the first article. It may only be remarked, that my theory is not opposed by the facts; that I take the earth nearly as it stands at present; and that I lay hold of none of those suppositions which are often used in reasoning concerning the former condition of the earth. But, as I here offer a new idea upon this subject of the sediments deposited by the

waters that, in my opinion, gave rise to the upper stratum of the earth, it will not be improper to exhibit the reasons upon which it is founded.

The vapours exhaled from the earth produce rain, dews, thunder, lightning, and other meteors. These vapours, therefore, are mixed with particles of water, air, sulphur, earth, &c.; and it is the solid, earthy particles which constitute the slime or mud under consideration. The purest rain-water deposits a quantity of this mud; and, when a quantity of dew is collected, and allowed to corrupt, it produces a greater proportional quantity of mud, which is fat, unctuous, and of a reddish colour.

The upper stratum of the earth is composed of this mud, mixed with particles of animal and vegetable substances, or rather with particles of stone and sand. It is worthy of remark, that most arable land is reddish, and more or less blended with heterogeneous matters. The particles of stone or of sand found in the upper stratum are of two kinds; the one is gross and heavy, the other fine, and sometimes impalpable. The gross is detached from the inferior stratum by labouring the ground; or, rather, the upper stratum, by penetrating the inferior, which is composed of sand or gravel, forms what is called *fat*, or *fertile sand*. The finer species proceeds from the air, falls down with the dew or rain, and intimately incorporates with the vegetable mould, or upper stratum.

This last is nothing more than the dust, transported by the air, and again deposited by rain or a moist atmosphere. When the quantity of this mud is great in proportion to the particles of stone or sand, the soil is red and fertile; if it be considerably mixed with animal and vegetable substances, it is blackish; but if the quantity of mud and of vegetable and animal substances be small, the soil is white and barren; and even when the particles of sand, stone, or chalk, which compose these barren soils, are mixed with a considerable quantity of animal and vegetable substances, they become black and light, but have very little fertility. According, therefore, to the different proportions of these three ingredients, the soil is more or less fertile, and differently coloured.

In order to acquire distinct ideas concerning the strata of the earth, we shall take for an example the pits at Marly-la-Ville, which are exceedingly deep. This place is situated in a high, but flat and fertile country, and its strata lie horizontally. I procured specimens of all these strata in their order from M. Dalibard, an eminent botanist, and a man of science; and, after having proved, with aqua fortis, the nature of the matters they respectively consist of, I arranged them in the following table.

Table of the different Beds of Earth at Marly-la-Ville, to the Depth of 100 *Feet.*

	Feet.	Inch.
1. A free reddish earth, mixed with a large quantity of mud, a little vitrifiable sand, and a greater proportion of calcinable sand, or gravel	13	
2. A free earth mixed with gravel and with more vitrifiable sand .	2	6
3. Mud mixed with a large quantity of vitrifiable sand, which made but a small effervescence with aqua fortis	3	
4. Hard marl, which effervesced violently with aqua fortis	2	
5. A marly stone very hard . . .	4	
6. Marl in powder, mixed with vitrifiable sand	5	
7. Fine vitrifiable sand	1	6
8. Marl resembling earth mixed with a little vitrifiable sand	3	6
9. Hard marl, in which was found genuine flint	3	6
10. Gravel, or marl in powder . .	1	
11. Eglantine, a hard ringing stone of the grain of marble	1	6
12. Marly gravel	1	6
13. Marl in the form of hard stone, with a fine grain	1	6
Carried over	43	6

	Feet.	Inch.
Brought over	43	6
14. Marl like stone, with a coarser grain	1	6
15. Marl still more gross	2	6
16. Fine vitrifiable sand, mixed with fossil sea shells, which had no cohesion with the sand, and which still preserve their natural colours	1	6
17. Fine gravel or marl-dust . . .	2	
18. Marl in the form of a hard stone .	3	6
19. Marl in the form of coarse powder	1	6
20. Hard stone, calcinable like marble	1	
21. A gray vitrifiable sand, mixed with fossil shells, particularly with oysters and spondyles, which had no cohesion with the sand, and were not petrified	3	
22. A white vitrifiable sand, mixed with the same shells	2	
23. A vitrifiable sand with red and white streaks, and mixed with the same shells	1	
24. A coarser vitrifiable sand, mixed with the same shells	1	
25. A fine, gray, vitrifiable sand, mixed with the same shells	8	6
26. A fine unctuous sand, with very few shells	3	
27. Brown free-stone	3	
Carried over	78	6

		Feet.	Inch.
	Brought over	78	6
28.	Vitrifiable sand, striped with red and white	4	
29.	A white vitrifiable sand . . .	3	6
30.	A reddish vitrifiable sand . . .	15	
	Total depth of the pit	101	

I formerly mentioned, that I had examined all these substances with aqua fortis, because no other test can enable us to make real distinctions between earthy bodies of the same or of different appearances. Those which effervesce and suddenly dissolve, on the application of the aqua fortis, are generally calcinable. Those, on the other hand, upon which that acid makes no impression, are vitrifiable.

From this enumeration of strata it is evident, that the land at Marly-la-Ville was formerly covered with the sea, to the depth of 75 feet, since shells are found 75 feet below the surface. Those shells have been collected and deposited by the water, together with the sand, which contains them; and the whole superior strata, except the uppermost, have been transported thither by the motion of the waters, and deposited in the form of sediment; as is apparent from their horizontal position, and from the mixture of sand, shells, and marl, which last is composed of decayed shells: even the upper stratum has been almost wholly formed of slime or mud, with a small mixture of marl.

I have chosen this example, because it is least favourable to my theory; for it appears, at first view, difficult to conceive how the mud deposited by the dew and rains should produce a bed of vegetable soil thirteen feet thick. But it ought to be remarked, that a soil of this thickness is rarely to be found, especially in high countries. The general run of soils is from three to four feet, and often they exceed not one foot. The soil is thickest in plains surrounded with hills; because the rains daily bring fresh supplies from the higher grounds. But, abstracting from this supposition, it is plain, that the upper strata formed by the sea are thick beds of marl. It is natural to think, that the upper stratum was originally much thicker, and that, beside the thirteen feet, the sea would leave a considerable quantity of marl. But this marl, being exposed to the action of the air, of rains, and of the rays of the sun, would soon be reduced into a fine powder. The sea would not leave this land suddenly, but would continue for some time occasionally to cover it, either by the motion of the tides, or by extraordinary swells during great storms; and, of course, the upper stratum would be mixed with mud, clay, and other slimy bodies. After being entirely above the reach of the waves, plants would begin to grow, and the soil would constantly accumulate, and be tinged with a reddish colour by the mud deposited by dews and rain. Culture would still farther increase both its fertility and its thickness, and, by al-

lowing the dews and rains to penetrate deeper, would in process of time produce this soil of thirteen feet.

I shall not here examine, whether the reddish colour of vegetable mould proceeds from a quantity of iron contained in the mud deposited by rain and dews. This point, which is of some importance, shall be discussed when we come to treat of minerals. It is sufficient to have given a view of the manner in which the upper stratum has been formed: we shall now prove, by other examples, that the formation of the interior strata of the earth must likewise have originated from the operation of the waters.

The upper stratum of the globe, says Woodward, that magazine for the formation and support of animals and vegetables, is mostly composed of vegetable and animal matter, and is in perpetual fluctuation. All the animals and vegetables which have existed since the creation, have successively extracted from this stratum the materials of which their bodies are constructed; these they again restore at their dissolution, where they remain prepared for the successive formation of new bodies of the same species; the matter which forms one body being naturally disposed to make another of the same kind*. In uninhabited countries, where the woods are never cut, nor the herbs broused by cattle, the soil is constantly augmenting. The soil, in all woods, even in those which are occasionally cut,

* See Woodward's Essay, p. 136.

is from six to eight feet thick, and has originated from the leaves, and other decayed parts of vegetables. I have often remarked, that, upon an old Roman way which runs across Burgundy, the stones with which it was constructed are covered with a black mould of more than a foot thick, and that it nourishes trees of a considerable size. This soil could only be produced by the gradual and successive destruction of vegetable bodies. As vegetables derive more of their substance from the air and water than from the earth, when they decay, they add more to the soil than they extracted from it. Besides, forests collect and retain vapours and moisture; and, of course, in old woods, the soil is greatly augmented. But, as animals restore much less to the earth than they take from it; and, as men consume vast quantities of wood and herbs for fewel and other purposes, it follows, that the vegetable soil of populous countries must continually diminish, and become, in time, like those of Arabia Petrea and other eastern countries, which were first inhabited, where nothing is now to be found but sand and salts: for the fixed salts of plants and of animals remain, while all the other parts volatilize, and are carried off by the air.

Let us next examine the position and formation of the interior strata. The earth, says Woodward, wherever it has been dug, is composed of beds or strata, one above another, in the same manner as if they had proceeded from successive sediments deposited by water. The

beds which lie deepest are thicker than those immediately above them, and they are gradually thinner till they arrive at the surface. Sea shells, teeth, and bones of fishes, are found in these beds, and not only in those which are soft, as chalk, clay, and marl, but even in beds of hard stone, marble, &c. These productions of the sea are incorporated with the stone, and, when separated, leave in the stone the figure of their surface exactly delineated. "I was abundantly assured," says this author, "that the circumstances of these things in remoter countries were much the same with those of ours here: that the stone, and other terrestrial matter, in France, Flanders, Holland, Spain, Italy, Germany, Denmark, Norway, and Sweden, was distinguished into strata, or layers, as it is in England: that those strata were divided by parallel fissures: that there were inclosed in the stone, and all the other denser kinds of terrestrial matter, great numbers of shells, and other productions of the sea; in the same manner as in that of this island. To be short, by the same means I got sufficient intelligence that these things were found in like manner in Barbary, in Egypt, in Guiney, and other parts of Africa: in Arabia, Syria, Persia, Malabar, China, and other Asiatic provinces: in Jamaica, Barbadoes, Virginia, New England, Brasil, Peru, and other parts of America." pp. 6, 41, 42, &c.

Woodward gives no authority for his assertion, that shells are found in the strata of Peru. But as, in general, his facts are true, I doubt not

but his information has been good; and I am persuaded that shells exist in the strata of Peru, as well as every where else. I make this remark on account of a doubt which has been entertained, and which shall afterwards be considered.

In digging a well at Amsterdam, 232 feet deep, the strata were arranged in the following order: 7 feet of vegetable soil; 9 feet of turf; 9 feet of soft clay; 8 feet of sand; 4 of earth; 10 of clay; 4 of earth; 10 of sand; 2 of clay; 4 of small white sand; 5 of dry earth; 1 of soft earth; 14 of sand; 8 of clay mixed with sand; 4 of sand mixed with shells; then 102 feet of clay; and, *lastly*, 31 feet of sand *.

It is uncommon to dig so deep before we find water: but this fact is remarkable in many other respects. 1st, It demonstrates that the sea communicates not with the interior parts of the earth by means of filtration: 2d, That shells are found 100 feet below the surface in a country extremely low; and, consequently, that the land of Holland has been elevated 100 feet by the sediments of the ocean: 3d, It may be concluded, that the bed of clay of 102 feet, and the bed of sand, 31 feet of which only had been dug, and whose actual thickness is unknown, lie near to the ancient and original earth, that existed before the motion of the waters began to change its surface. In the first article, it was remarked, that, in order to discover the ancient

* See Varenii Geograph. Gen. p. 46.

earth, we must dig in the northern, rather than in the southern regions; and in the low and plain, rather than in the elevated countries. These circumstances nearly concurred in the present case. We only wished that the pit had been dug deeper, and that the author had informed us, whether shells, or other sea bodies, were intermixed with the last strata of clay and of sand. This experiment confirms what was formerly advanced, that the strata are always thicker in proportion to their depth.

We have some examples of quarries and pits of considerable depths, of which the different strata have been examined and described; such as the pit of Amsterdam, which descends 232 feet, and that of Marly-la-Ville, which is 100 feet deep. Many other examples might be given, if observers had agreed in their denominations. But some give the name of *marl* to white clay; others apply the term *flint* to round calcareous stones; and others give the denomination of *sand* to calcareous gravel. Hence little advantage can be derived either from their researches or their long dissertations on these subjects; because we are under a perpetual uncertainty with regard to the nature of the substances they describe. We shall, therefore, confine ourselves to the following examples.

An excellent observer has written to one of my friends, in the following terms, concerning the strata in the neighbourhood of Toulon: "To the north of the city of Toulon," he remarks, "there is an immense quantity of stony matter,

which occupies the declivity of the chain of mountains, and stretches through the valley from east to west; and one part of it forms the soil of the valley, and loses itself in the sea. This stony matter is commonly called *saffre;* but it is that species of tufa which is denominated *marga toffacea fistulosa* by naturalists. M. Guettard desired me to furnish him with all the information I could obtain concerning this saffre, as well as specimens of the matter itself, that he might examine it, and give a detail of its qualities in his memoirs. I sent them both; and I believe I have satisfied him; for he has thanked me for the information I communicated. He tells me, that he is to return to Provence and Toulon in the beginning of May. . . . . M. Guettard, however, will probably give us nothing new upon this subject; for M. de Buffon has exhausted it in the first volume of his Natural History, under the article, *Proofs of the Theory of the Earth;* and it appears, that, in composing this article, he had in his eye the mountains of Toulon and their ridge.

"At the commencement of this ridge, which consists of a more or less hard tufa, we find, in small cavities of the nucleus of the mountain, quantities of very fine sand, which are probably the balls mentioned by M. de Buffon. After breaking other superficial parts of the nucleus, we find numbers of sea shells incorporated with the stone. . . . . I have several of these shells, the enamel of which is well preserved. I will send them soon to M. de Buffon."

M. Guettard, who has made more observations of this kind than any other naturalist, expresses himself in the following terms, when he treats of the mountains in the neighbourhood of Paris *.

" Below the vegetable soil, which exceeds not two or three feet, is placed a bed of sand from four or six to twenty, and often thirty feet thick. This bed is commonly replete with stones of the nature of grind-stone. . . . . . In some districts, we meet with detached masses of free-stone in this sand bed.

" Below this sand, we find a tufa, from ten or twelve, to thirty, forty, and even fifty feet thick. This tufa is not commonly of one equal thickness. It is frequently cut by different strata of spurious or clayey marl, of the *cos* which the workmen call *tripoli*, or of good marl, and even by small beds of pretty hard stones. . . . . . Under this bed of tufa are found those which furnish stones for building. These beds vary in thickness: at first they exceed not one foot. In some districts, three or four of them lie above each other. They are succeeded by one of about ten feet, both the surface and interior parts of which are interspersed with moulds or impressions of shells. It is followed by another about four feet, which rests upon one from seven to eight, or rather upon two of three or four feet. After these beds, there are several others, which together

* Lettre de M. Bussy à M. Guenaud de Montbeillard, Toulon, Avril 16, 1775.

form a mass of at least three fathoms. This mass, after piercing a bed of sand, is succeeded by clays.

"This bed of sand is earthy and reddish, and is from two and a half to three feet thick. After this comes a bed of spurious clay of a blueish colour; it is a clayey earth mixed with sand; the thickness of this bed is about two feet, and is followed by another of five, which consists of a smooth black clay, the broken portions of which are nearly as brilliant as jet. Lastly, this black clay is succeeded by a blue, which forms a stratum from five to six feet thick. In these different clays we find pyrites of a pale yellow colour, and of various figures. . . . The water found below all these clays prevented us from penetrating any deeper."

The strata in the quarries of the district of Moxouris, above the suburb of Saint-Marceau, are disposed in the following order.

	Feet.	Inches.
" 1. Vegetable soil	1	
" 2. Tufa	12	
" 3. Sand	18	
" 4. Yellowish earth	12	
" 5. Tripoli; that is, a white, fat, compact earth, which hardens when exposed to the sun, and marks any substance in the same manner as chalk	30	
" 6. Flints, or a mixture of greasy sand	12	
" 7. Rock	2	

	Feet.	Inches.
" 8. A stratum of small stones, from one to two feet . .	2	
" 9. Two strata of stone, which dissolve by the operation of the air and weather . . .	1	
" 10. Earth and gravel . . .	1	6
" 11. Free-stone	1	6
" 12. Very hard lime-stone . .	1	
" 13. A greenish stratum . . .	1	6
" 14. A tender calcareous stone, which forms two strata, one of eighteen inches, and the other of two feet	3	6
" 15. Several small beds of bastard calcareous stone. They precede the sheet of water, common in pits. This sheet the diggers are obliged to remove before they can obtain the potter's clay, which lies between two waters*.		
In all	99"	

I have given this specimen for want of a better; for the uncertainties with regard to the nature of the different strata are apparent. We cannot, therefore, be too anxious in recommending to observers to be more exact in defining the nature of those materials they attempt to describe. They may at least distinguish them into vitrescent and calcareous, as in the following example.

* Mem. de l'Acad. des Sciences, année 1756.

The soil of Lorrain is divided into two great zones: the eastern, which covers the chain of *Voges*, which are primitive mountains composed entirely of vitrifiable and crystallized matters, as granite, porphyry, jasper, and quartz, disposed in detached blocks or groups, and not in regular strata or beds. In all this chain of mountains, there is not the smallest vestige of any marine production; and the hills which proceed from them consist of vitrifiable sand. Where they terminate, and upon a continued bounding line of their descent, the other zone commences, which is totally calcareous, disposed in horizontal beds, and replete, or rather completely formed, of sea bodies *.

The banks and beds of the earth in Peru are perfectly horizontal, and correspond sometimes at a great distance in different mountains, most of which are two or three hundred fathoms high. They are in general inaccessible, and often as perpendicular as walls, which gives us an opportunity of perceiving the extremities of their horizontal strata. When any of them happen to be round and detached from others, each bed appears like a very flat cylinder, or a section of a cone of no great height. These different beds, placed one above another, and distinguished by their colour and various contours, often resemble a regular and artificial structure. In this country, we see the mountains perpe-

* Note communicated to M. de Buffon, par M. l'Abbé Bexon, March 15, 1777.

tually assuming the appearance of ancient and sumptuous palaces, of chapels, of castles, and of domes. They are sometimes fortifications composed of long curtins, and defended with bulwarks. After examining these objects, and the correspondence of their strata, we can hardly entertain a doubt, that the circumjacent land has not, at some period, been really sunk. It appears, that those mountains, whose bases were most solidly supported, remained as monuments to indicate the height which the soil of these countries anciently possessed *.

The Mountain of Birds, called in Arabic *Gebeliter*, is so equal from top to bottom, for the space of half a league, that it rather resembles a wall regularly built by the hands of man, than a rock formed in this manner by the operation of Nature. The Nile washes this mountain a long way; and it is distant from Cairo in Upper Egypt four and a half days' journey †.

To these observations, I shall add a remark made by most travellers, that, in Arabia, the soil is of various natures. The region nearest to Mount Libanus presents nothing but broken and overturned rocks, and is called *Arabia Petrea*. The removal of the soil, by the movement of the waters, has rendered this country almost totally barren; whilst the lighter mud, and all the good earth, have been carried to a greater distance, and deposited in that part of

* Bouguer, Figure de la Terre, p. 89.

† Voyage du P. Vansleb.

the country called *Arabia Felix.* Besides, the *revers* in Arabia Felix, as well as every where else, are more rugged toward the African Sea, *i. e.* to the west, than toward the Red Sea, which is on the east.

The earth consists of parallel and horizontal strata, not in the plains only, but, in general, the hills and mountains have the same structure. The strata of the mountains are even more conspicuous than those of the plains; for the plains are commonly covered with great quantities of sand and earth brought from the higher grounds by the waters; and, therefore, to find the ancient strata, we must dig deeper in the plains than in the mountains.

I have often remarked, that, when the top of a mountain is level, its strata are likewise level; but, when the top is not horizontal, the strata follow the direction of its declivity. It has frequently been alleged, that the beds of quarries incline to the east. But in all the chains of rocks which I have examined, I found, that these beds always follow the declivity of the hill, whether its direction be east, west, south, or north. In raising stones from the quarry, they are always separated according to their natural position; and, if cut in a contrary direction, it is impossible to raise them of any considerable size. In all good masonry, the workmen place the stones in the direction in which they lay in the quarry; if laid in an opposite position, they will split, and be unable to resist the weight of the incumbent building. Hence we may conclude,

that stones have been originally formed in horizontal beds; that these beds have been successively accumulated above each other, and have been composed of materials, the resistance of which is stronger in that than in any other direction.

Every stratum, of whatever kind, whether it be horizontal or inclined, is of an equal thickness through its whole extent. In the quarries round Paris, the stratum of good stone is but about 18 or 20 inches thick throughout. In the quarries of Burgundy, the stone is much thicker. The same inequalities take place in marbles. The white and black marbles are thicker than those that are coloured; and there is a hard stone with which the people of Burgundy cover their houses, that exceeds not an inch in thickness. Thus, different strata differ much with regard to thickness; but each stratum uniformly preserves the same thickness through its whole extent. This difference is so great, that strata are to be found from less than a line, to 1, 10, 20, 30, and 100 feet thick. Both ancient and modern quarries, which are dug horizontally, the shafts of mines, and the working of lead, either longitudinally or transversely, prove that strata extend a great way on all sides. "It is well known," as the historian of the academy observes, "that all stones have originally been a soft paste, and that, as stones are almost every where to be met with, the surface of the earth in all these places, at least to a certain depth, must have consisted of mud and slime. The shells found

in most quarries demonstrate, that this mud was an earth diluted by the water of the sea; and, consequently, that the sea once covered all these places; but the sea could not cover them, without, at the same time, covering all places that were lower, or on the same level. Now, it is impossible that the sea could cover all those places where there are quarries, without covering the whole surface of the globe. If the mountains were then formed, the sea must also have covered them; for they are full of rocks and quarries, and shells are often found in them.

"The sea, then," continues he, "covered the whole earth; and hence all the beds of stone in the plains are horizontal and parallel: the fishes, therefore, were the most ancient inhabitants of the globe; for neither land animals nor birds could exist. But how has the sea retired into those vast basons which it now occupies? The most natural supposition is, that the earth, at least to a certain depth, was not all equally solid, but interspersed with vast vaults or caverns, the arches of which would remain for a time, and at last suddenly fall in. The waters would then rush into these hollows, fill them up, and leave a part of the surface dry, which would become a convenient habitation for land animals and birds. The shells found in quarries strongly confirm this idea; for nothing but the bony parts of fishes could be preserved so long in the earth. Besides, shells commonly lie in vast masses in certain

parts of the sea, where they remain immoveable, and form a species of rocks or banks; they could not, therefore, follow the sea, which suddenly abandoned them. It is for this last reason that we find such numbers of fossil-shells, and so few vestiges of other fishes, which is a farther proof that the waters retired with rapidity into their present basons. When the vaults sunk down, it is very probable that mountains were elevated by the same cause, and placed upon the surface with rocks and quarries already formed. But the beds of these quarries could not preserve their original horizontal position, unless they were raised exactly perpendicular to the surface, which would rarely happen. Thus, as we formerly remarked *, the beds of stones in mountains are all inclined to the horizon, though they be parallel to each other; for they changed not their position with regard to one another, but with regard only to the surface of the earth †.

These parallel beds of earth or of stone, which have been formed by sediments of the ocean, often extend to considerable distances. We even find, in hills separated by valleys, beds of the same materials upon equal levels. This observation has a perfect correspondence with the equal altitudes of opposite hills. The truth of this fact may be easily established; for, in all

* See Mem. de l'Acad. ann. 1705, p. 30.

† Ibid. ann. 1716, p. 14.

hills separated by narrow valleys, where stone or marble is found on one hill, we uniformly find these very substances, at the same level, on the opposite hill. I have traced a quarry of marble twelve leagues in length; its breadth is also considerable, though I have not been able to ascertain it with precision. I have often observed, that this bed of marble has every where the same thickness; and that, in hills separated by a valley of 100 feet deep, the same bed always appeared at the same altitude. I am firmly persuaded, that this observation holds with regard to all quarries of stone or of marble which contain shells; but it applies not to beds of freestone. We shall afterwards explain why freestone is not dispersed, like other matters, in horizontal beds, but in blocks, irregular both in form and position.

It has likewise been remarked, that, on the opposite sides of straits of the sea, the strata are the same. This observation is important, and may lead to the discovery of those necks of land or islands which have been separated from the Continent. It proves, for example, that England has been separated from France, Spain from Africa, and Sicily from Italy: and it is to be regretted, that the same observation has not been made upon all straits. I have no doubt but it will hold universally. We know not, whether, in the Straits of Magellan, the longest we are acquainted with, the same strata are to be found at the same latitude. But we perceive, from

very exact charts, that the opposite coasts, which are high, have corresponding angles, like those observable in our inland mountains; and this farther proves Terra del Fuego to have been formerly a part of the Continent of America. The same remark has been made with regard to the Strait of Frobisher; and the island of Friesland appears to have been separated from the Continent of Greenland.

The Maldivia islands are separated from each other by small branches of the sea; and, on each side of the opposite islands, the strata of rocks, &c., are the same. These islands, which, when taken together, extend about 200 leagues in length, were formerly one. They are divided into 13 provinces, called *Clusters*. Every Cluster contains a great number of small islands, most of which will soon be under water. It is remarkable, that each of these 13 Clusters is surrounded with a chain of rocks of the same stone, and that there are only three or four small and dangerous openings, through which each of them can be approached. They are all placed in a line, with their ends to each other, and appear evidently to have been once a long mountain crowned with rock *.

Several authors, as Verstegan, Twine, Sommer, but particularly Campbell, in his description of the county of Kent, give striking proofs that England was formerly joined to France,

* See Voyag. de Franc. Pyrard, vol i. p. 107.

and that the neck of land that divides them had been carried off by the sea, which retired, and left a great quantity of low marshy ground along the southern coasts of England. As a farther proof of this fact, Dr. Wallis has attempted to show an affinity between the ancient language of the Gauls and that of the Britains; and he adds several other remarks, which shall be related in the following articles.

If travellers observed the figure of lands, the position of mountains, and the windings of rivers, they would perceive that opposite hills are not only composed of the same materials at the same altitudes, but that they are also nearly of an equal height. In all the places where I have travelled, I uniformly remarked this equality in the height of opposite hills, especially when they are separated by valleys not above a fourth or a third of a league wide. In valleys of greater width, it is difficult to judge of the height or equality of hills; for, on looking over a level and extensive plain, it appears to rise; and distant hills seem to sink. But this is not the place to account for these phænomena. Besides it is not easy to determine by the eye the middle of a large valley, unless it be traversed by a river. But, in narrow valleys, the judgment of the eye is more certain. That district of Burgundy comprehended between Auxerre, Dijon, Autun, and Bar-sur-seine, of which a considerable portion is called *le Bailliage de la Montagne*, is one of the most elevated parts of France. From one

side of these mountains, which are only of the second order, the water runs to the ocean, and, from the other, to the Mediterranean. There are points of partition, as at Sombernon, Pouilli in Auxois, &c., where the water may be turned at pleasure either to the ocean or the Mediterranean. This high country is intersected with a number of small valleys, and most of them are watered with rivulets. Here I have a thousand times observed the corresponding angles of the hills, and their equality as to height; and I can with confidence affirm, that the salient or prominent angles are uniformly opposed to the concave ones, and that the heights of the two sides are nearly the same. The farther we advance in this high country, where are the points of partition mentioned above, the mountains rise the higher. But this height is always the same on the opposite sides of the valleys, and the hills rise or fall equally. The same observation I have repeatedly made in several other provinces of France; but they extend not to very high mountains; for these are more irregular as to height, and often terminate in unequal points or peaks. In frequently traversing the Alps and Appennines, I observed that the angles, in effect, corresponded: but that it is almost impossible to judge by the eye, concerning the equality or inequality in the heights of opposite mountains; because their tops are lost in the clouds.

The different strata composing the earth are not arranged according to their specific gravities.

Beds of heavy matter are frequently placed above those of lighter. Solid rocks are often supported by beds of earth, clay, or sand, which are greatly inferior in specific gravity. This is the case with most hills, and is easily perceived. But, in high mountains, the summits are not only rocks, but these rocks are supported by others; and this structure runs through such an extent of country, where one mountain rises out of another, that it is difficult to determine whether they are founded on earth, or of what nature this earth is. I have seen rocks cut perpendicularly for some hundreds of feet; but these rocks rested upon other rocks, without my being able to perceive where they ended. May we not, however, be allowed to conclude from the less to the greater? Since the rocks of small mountains, the bases of which are visible, rest upon earths less heavy and less solid than stone, is it not reasonable to think, that earth is likewise the basis of high mountains? * Besides, all

* I acknowledge that this conjecture, derived from analogy, is not sufficiently founded. The conjecture hazarded above was written thirty-four years ago. Since that time, I have acquired ideas and collected facts which convince me that the great mountains, composed of vitrescent materials, and produced by the action of primitive fire, are connected immediately with the interior rock of the globe, which is also a vitreous rock of the same kind. These great mountains are a part of this immense rock, and are only prolongations or eminences formed upon the surface of the globe, at the time of its consolidation. Hence we ought to regard them as constituent parts of the original mass of the earth.

I have here advanced tends to prove, that heavy bodies might be accumulated, by the motion of the waters, above light ones; and, if this really takes place in most hills, it is probable that it has happened in the manner pointed out by my theory. But, should it be objected, that I had no reason to suppose, that, prior to the formation of mountains, the heavier matter was below the lighter; I answer, that I affirm nothing with regard to this article; because there are many ways by which this effect might be produced, whether the heavy matter was above or below, or placed indiscriminately: for, in order to conceive how the sea could first form a moun-

But the hills, or smaller mountains, which rest upon clay or vitrifiable sand, have been formed by the motion and sediments of the waters, at a time long posterior to the formation of the great mountains by the primitive fire *. It i in these points or projections, which form the nucleus of mountains, that tha veins of metals, though their height be considerable, are not of the highest kind, but of a mean height and uniformly arranged, *i. e.* they rise by gradual elevations, and are connected with a considerable chain of mountains, which are occasionally interrupted by valleys.

* The internal parts of the primitive mountains which I have penetrated, either in pits or in the galleries of mines, to the depth of twelve and fifteen hundred feet, are entirely composed of *pure* vitreous *rock*, in which there are slight and irregular fissures, through which the water issues, and vitriolic and metallic solutions. From this fact we may conclude, that the whole nucleus of these mountains is a pure rock, adhering to the primitive mass of the globe. We indeed find, upon their sides, and upon the margins of the valleys, masses of clayey earth, and banks of calcareous stones, at considerable depths. But these are only the remains of those materials which filled up the cavities of the earth, and must be referred to the second epoch of Nature.—*Note communicated by M. de Grignon to M. de Buffon, Aug.* 6, 1777.

tain of clay, and then crown it with rocks, we have only to consider, that the sediments might be transported from different places, and that they might consist of different materials. The sea might transport from one place several sediments of clay, and afterwards deposit sediments of stony matter; either because all the clay at the bottom, or on the coasts, was exhausted, and then the waves would attack the rocks; or, rather, because the first sediments were transported from one place, and the last from a different one. Besides, the latter corresponds exactly with experience; for, it is a known fact, that beds of earth, stone, gravel, sand, &c., follow no rule of arrangement, but are placed indifferently, and, as it were, by chance, one above another.

This chance, however, ought to have some rules, which can only be discovered by analogy and probable conjecture. We have seen, that, according to my theory of the formation of the globe, its interior parts should consist of vitrified matter, similar to vitrified sand, which is only the fragments of glass, and of which the clays are the scoriæ, or decomposed parts. Agreeable to this supposition, the centre of the earth, and even near the surface itself, should be composed of glass or vitrified matter, and above this should be found sand, clay, and other scoriæ. Thus, the earth, in its original state, was a nucleus of glass, or of vitrified matter, *either compact like glass, or divided like sand* (for that circumstance depends on the degree of

heat applied); above this matter was sand; and, lastly, clay. The soil, or external covering, was produced from the air, and the mud of water; and it is more or less thick according to the situation of the ground; more or less coloured, according to the different mixtures of mud, sand, clay, and the parts of decayed animals and vegetables; and more or less fertile, according to the abundance or deficiency of these parts. To show that this account of the formation of sand and clay is not altogether imaginary, I shall add a few remarks.

I suppose the earth, in its first state, to have been a spheroid of compact glass, covered with a thin crust of pumice-stone, and other scoriæ of melted matter. The agitation of the air and of the water would soon reduce this crust of pumice into powder or sand, which, by uniting into masses, would give rise to free-stone and flints, the varieties of which, with regard to colour and density, depend upon the different degrees of fineness of the sand that composed them.

The constituent parts of sand unite by the application of fire, become very hard, compact, and more or less transparent, according to the purity of the sand: but, on the other hand, when exposed to the action of the air, it exfoliates, falls down in the form of earth, and may thus produce clays of different kinds. This dust, which is sometimes yellow, sometimes brilliant, and is used to dry writings, is nothing else than a fine sand, somewhat corrupted, and nearly re-

duced to an elementary state. Its particles, in time, become so attenuated and divided, that they lose the power of reflecting light, and acquire all the properties of clay. On examining a piece of clay, many of these shining or talky particles appear; because they have not yet entirely lost their original form. Sand, therefore, in process of time, may produce clay; and this clay, by a farther division, acquires the qualities of mud or slime, a vitrifiable matter of the same nature with clay.

This theory is confirmed by daily experience. In washing sand, the water becomes impregnated with a black, soft, fatty earth, which is a genuine clay. The mud swept from streets paved with free-stone, is black and very fat, and, when dried, it discovers itself to be an earth of the same nature with clay. Clay, taken from places where there is neither flint nor free-stone, and diluted with water, always precipitates a great quantity of vitrifiable sand.

But, what clearly demonstrates the existence of sand, and even of flint and glass, in clay, is, that the re-union of its parts, by the action of fire, restores it to its original form. Clay, when heated to the degree of calcination, is covered with a hard coat of enamel; if its internal parts are not vitrified, they become so extremely hard as to resist the file; they strike fire with the hammer, and acquire all the properties of flint: a great degree of heat melts and converts them into real glass.

Clay and sand, therefore, are substances per-

fectly analogous, and of the same kind. If clay can be condensed to flint, and even to glass, why may not sand, by resolution, become clay? Glass appears to be the true elementary earth, and all mixed bodies are only glass in disguise. Metals, minerals, salts, &c., are only a vitrifiable earth: common stone, and other analogous bodies, testaceous and crustaceous shells, &c., are the only substances which cannot be vitrified, and which seem to form a distinct class. I had not then made those experiments which have since convinced me, that calcareous substances, like all others, may be reduced to glass. To produce this effect, nothing more is necessary than a fire more violent than that of our common furnaces. I reduced lime-stone to glass by a good burning glass. Besides, M. d'Arcet, an able chemist, melted calcareous spar, without the addition of any other matter, by means of a porcelain furnace belonging to M. le Compte de Lauragais. But these operations were performed several years after the publication of my *Theory of the Earth*. I knew only that, in the iron furnaces, the light, white, spongy matter, similar to pumice-stone, which issues from them when overheated, is nothing but a vitreous substance, proceeding from the calcareous bodies thrown into the furnace to assist the fusion of the iron ore. The sole difference between the vitrification of calcareous and vitrescent substances is, that the latter are immediately vitrified by the action of a violent fire alone; but calcareous bodies, before they are vitrified, pass through a state of calci-

nation, and form a line. But, like all other substances, they vitrify, even in our common furnaces, whenever they are mixed with vitrescent matters, especially with those which, like the *aubuë*, or slimy earth, yield most easily to the fire. Hence we may safely conclude, that, in general, every material of which this globe is composed, may be reduced to its primitive state of glass, if a sufficient degree of heat is applied. The former, by the action of fire, may be converted into a homogeneous, hard, and transparent substance, without any diminution of its weight, and upon which no farther change can be made. The latter, on the contrary, which consist of more active and volatile principles, calcine in the fire, lose more than a third of their weight, and resume the form of simple earth, without any other change than the resolution of their constituent parts. If these bodies be excepted, which are few in number, and of which the combinations produce few varieties in nature, all other substances, and particularly clay, may be converted into glass, and, consequently, are only glass in a decomposed state. If fire quickly vitrifies these substances, glass itself, whether simple or in the form of sand or flint, naturally, but by a slow and insensible progress, resolves into clay.

In countries where flint is the predominant stone, the fields are commonly strewed with its fragments: if the place be uncultivated, and if the flints have remained long exposed to the air without being moved, their upper sur-

face is always white; but the surface next the ground preserves its natural colour, which is very brown. When these flints are broken, the whiteness appears to be not superficial only, but penetrates more or less into their internal parts, and forms a belt, which in some is not very deep, but in others occupies nearly the whole stone. This white part is somewhat granulated, perfectly opaque, as tender as free-stone, and adheres to the tongue like the boles. But the other portion of the flint is smooth and polished, has neither thread nor grain, and preserves its original colour, its transparency, and its hardness. When this half decomposed flint is put into a furnace, the white part becomes red like a brick, and the brown part becomes exceedingly white. Why shall we conclude, with a famous naturalist, that flints of this kind are imperfect, and that they are not old enough to have acquired their perfect state? For why should they be all imperfect? And why should they be uniformly imperfect on the side only that is exposed to the air? It is, on the contrary, much more probable, that they are changed from the original state, and partly decomposed, and that they are gradually resolved into clay or bole. If this reasoning should appear to be unsatisfactory, expose to the air the hardest and blackest flint; in less than a year the colour of its surface will be changed; and, if the experiment be farther prosecuted, the flint will be found gradually to lose its hardness, its transparency, and its other spe-

cific characters, and make daily approaches to the nature of clay.*

Sand undergoes the same changes as flint. Every grain of sand may, perhaps, be considered as a small flint, and every piece of flint as a collection of fine sand cemented together. The first example of the decomposition of sand is exhibited in that shining, but opaque powder, called *mica*, with which clay and slate are always impregnated. The quartz, or perfectly transparent flints, in decomposing, produce fat and soft talks, such as those of Venice and Russia, which are as ductile and vitrifiable as clay; and it appears, that talk is the mean between glass, or transparent flint, and clay; but that the gross and impure flints, in decomposing, are converted into clay without any intermediate state.

Our made glass undergoes the same change; when long exposed to the air, it decomposes, and, as it were, corrupts. At first, it assumes a number of colours, then it exfoliates, and, in handling it, we perceive that many shining particles fall off. But, when its decomposition is farther advanced, it bruises between the fingers, and is reduced to a very white, talky, and impalpable powder. Art also imitates nature in the decomposition of glass and flint. "Est etiam certa methodus, solius aquæ communis ope, silices et arenam in liquorem viscosum eundemque in sal viride convertendi, et hoc in oleum rubicundum, &c. Solius ignis et aquæ ope, speciali ex-

perimento, durissimos quosque lapides in mucorem resolvo, qui distillans subtilem spiritum exhibet, et oleum nullis laudibus prædicabile *."

These matters shall be more fully considered when we treat of metals. We shall here only add, that the different strata of the globe consist either of materials which may be considered as actual vitrifications, or analogous to glass, and possessing its most essential qualities. It is also evident, that, from the decomposition of glass and flint, which daily takes place, there results a genuine clay. Hence we may conclude, with a high degree of probability, that sand and clays have originally been the scoriæ of burnt matter, especially when we join to the above circumstances, the proofs *a priori* which have been employed to show that the earth was formerly in a state of liquefaction occasioned by the operation of fire.

* Vid. Becher. Phys. Subterr.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE VIII.

Of Shells, and other Productions of the Sea, found in the Interior Parts of the Earth.

I HAVE often examined quarries, the stones of which were full of shells. I have seen whole hills composed of shells, and chains of rocks intermixed with shells through their whole extent. The quantity of shells, and other productions of the sea, is, in many places, so prodigious, that it is difficult to believe any more of them existed in their natural element. It is from this enormous quantity that no doubt remains of the earth's having continued for a very long time under the waters of the sea. The number of sea shells found in a fossil or petrified state is so amázing, that, were it not for this circumstance, we never should have had a proper idea of the surprising quantities of those animals to which the ocean gives birth. We must not, therefore, imagine, like those who talk and reason concerning things they never saw, that shells are only

to be found scattered here and there by chance, or in small heaps, like those of oysters thrown from our doors. They appear, on the contrary, in masses like mountains, in banks of 100 or 200 leagues in length. They may often be traced through whole provinces, and in masses of 50 or 60 feet thick. It is only after having learned these facts that a man is entitled to reason on this subject.

The shells of Turenne may serve as a striking example. Let us attend to the description given of them by the historian of the Academy*.

" Though figured stones, and even fossil shells, found in the bowels of the earth, were remarked in all ages and nations, they were generally considered, even by philosophers, as *lusus naturæ;* the production of them was ascribed to chance, or to some unaccountable and fortuitous train of circumstances; and, of course, this wonderful phænomenon added nothing to the stock of knowledge. An ignorant potter in Paris†, who knew neither Greek nor Latin, about the end of the 16th century, was the first man who ventured, in opposition to all the learned, to affirm, that fossil shells were real shells originally depo-

* Ann. 1720, p. 5.

† The correspondence of Palissy's ideas with those of the ancients, is worth remarking. " Conchulas, arenas, buccinas, calculos varie infectos, frequenti solo, quibusdam etiam in montibus reperiri, certum signum maris alluvione eos coopertos locos volunt Herodotus, Plato, Strabo, Seneca, Tertullianus, Plutarchus, Ovidius, et alii;" Vide Dausqui, Terra et Aqua, p. 7.

sited by the sea, in those places where they are found; that real animals, and particularly fishes, bestowed on figured stones their various forms, &c.; and he boldly defied the whole school of Aristotle to invalidate his proofs. His name was Bernard Palissy; and he was perhaps the most conspicuous example of a philosophical genius, unimproved by art or learning. His system, however, has lain dormant for near a century, and even his name has almost been forgot. At last, several philosophers revived Palissy's ideas; and science has derived great advantage from all the fossil shells and figured stones which have appeared in the earth: they are now, perhaps, become too common, and the consequences drawn from them too incontestible.

"But Reaumur's late observations on the subject are astonishing. He discovered a mass below ground of 130,680,000 cubic fathoms of shells, either whole or in fragments, without the least mixture of stone, earth, sand, or other foreign matter. Before this remarkable instance, fossil shells never appeared in such enormous quantities, nor without being mixed with other bodies. This prodigious mass lies in Turenne, more than 36 leagues from the sea. It is of great service to the peasants of that province; they use the shells for marl in fertilizing their lands, which would otherwise be perfectly barren.

"What the peasants dig out of the earth, to the depth of eight or nine feet, consists only of fragments of shells; but these fragments are

easily recognised to be those of real shells; for they still retain their original channels or furrows, and have only lost their lustre and varnish, as most shells do, after having remained long under ground. The smallest fragments are only dust; but we know them to be the dust of shells, because they consist of the very same matter with the larger fragments and the entire shells, which are sometimes found. The species both of the large fragments and of the entire shells, are easily distinguishable. Some of these species belong to the coast of Poitou, and others of them to foreign shores. This mass likewise furnishes corals, and other productions of the sea. *Falun* is the name by which this matter is distinguished in that province; and it is found, wherever the ground is dug, through an extent of about nine leagues square. The peasants never dig deeper than about 20 feet; because, says Reaumur, they imagine that the expense of labour would exceed the value of the commodity. They might, however, dig deeper. But our calculation of 130,680,000 cubic fathoms proceeds upon the supposition of only 18 feet deep, and 2,200 fathoms to the league. Every article, therefore, is undervalued, and this mass of shells must greatly exceed the above calculation; if the quantity be only doubled, this wonderful phænomenon will be greatly augmented.

" In physical facts, there are little circumstances often overlooked by the bulk of mankind, which are, notwithstanding, of great consequence in illustrating the subject. M. de Reau-

mur has remarked, that all the fragments of shells lie horizontally in the great mass; from which he concludes, that the fragments were not deposited at the same time with the entire shells, which originally formed this mass; because, says he, the superior shells would, by their weight, have broken the inferior ones, and the fragments, in that case, would necessarily have been disposed in a thousand different directions. The whole, therefore, whether entire or broken, must have been gradually transported thither by the sea, and, of course, their position must have been horizontal. But, though time alone was sufficient to break them down, and even to calcine them, it could not vary their original position. Their transportation must have been gradual; for, it is impossible that such an immense number of shells could be suddenly crowded together, and yet preserve a position uniformly horizontal; and their being assembled in one place, demonstrates this place to have once been the bottom of a gulf or bason.

" Though there are many vestiges of the universal deluge which is recorded in scripture, yet the mass of shells at Turenne could not be an effect of this deluge. Perhaps such an amazing mass is no where to be found, even in the bottom of the sea. But, supposing the deluge to have forced such a quantity from the ocean, they would necessarily be carried off with violence and precipitation; and, consequently, could never have been deposited in the same position. They must have been transported, slowly floating

in the waves; and, of course, their accumulation would require a much longer time than a year.

"Upon the whole, it is plain, that, either before or after the deluge, the earth, at least some parts of it, must have been in a very different situation from what it now appears; that the sea and land must have had a different arrangement; and that there was formerly a great gulf in the middle of Turenne. The changes recorded in history, or even in ancient fable, are inconsiderable; but they give us some idea of what might be produced in a long series of ages. M. de Reaumur conjectures, that Turenne was formerly a gulf of the sea, and that the shells were transported by a current. But this is only a mere conjecture, thrown out to supply the place of a fact as yet imperfectly known. Before any certain conclusion can be drawn, we must have geographical charts of all those places where shells are found below the surface of the earth. To accomplish this, much time and numberless observations are requisite. Science, however, may in time be carried thus far."

An attention to the following circumstances will lessen our surprise at this great collection of shells: 1. Shell-fish multiply prodigiously, and arrive at maturity in a very short time. The multitude of individuals in every species is a demonstration of their amazing fertility. In a single day, for example, a mass of oysters, of several fathoms in thickness, is often raised;

the rocks, to which they are attached, diminish considerably in a short time; and some banks are entirely exhausted. The following year, however, furnishes an equal quantity, and not the smallest diminution appears. It is even doubted, whether a natural bed of oysters was ever entirely exhausted. 2. The substance of shells is analogous to that of stone; they are long preserved when immersed in soft matter; and they easily petrify when connected with matter naturally hard: these fossil shells, therefore, and other productions of the sea found on land, being the spoils of many ages, must necessarily have accumulated into large masses.

We have already remarked the prodigious quantities of shells preserved in marble, lime-stone, chalk, marl, &c. They appear in masses like hills or mountains; and they often compose more than one half of the bodies in which they are contained. Sometimes they appear entire, and at other times in fragments, but large enough to enable us to distinguish their respective species. Here our knowledge of this subject, derived from observation, stops. But I go farther, and maintain, that shells are the medium employed by Nature in the formation of most stones; that chalk, marl, and lime-stone, consist entirely of the dust or fragments of shells; and, consequently, that the quantity of decomposed shells is infinitely greater than of those which have been preserved. These positions shall be fully established in the section upon

minerals; and I shall here only exhibit the point of view in which the different strata of the earth ought to be considered. The first bed, in which nothing of the original structure appears, is composed of mud deposited by dews, rains, and snow, and of particles of animal and vegetable substances. The inferior beds of chalk, marl, lime-stone, and marble, are composed of the spoils of shells and other sea bodies, mixed occasionally with entire shells or fragments of them; but clay and vitrifiable sand are the materials which compose the internal parts of the globe. These substances were vitrified at the time the earth assumed its figure, which necessarily implies, that the whole was then in a melted state. The different species of granite, flint, free-stone in large masses, slate, and coal, derive their origin from sand and clay, and are also disposed in beds. But tufa and pumice, free-stone and flint, in small or detached pieces, crystals, metals, pyrites, most minerals, sulphurs, &c., are matters, the formation of which is recent, when compared with that of marble, calcinable stones, chalk, marl, and other substances that are disposed in horizontal beds, and contain shells, or other relics of the ocean.

As the terms I have employed may appear obscure or ambiguous, it is necessary to explain them. By *clays*, I mean not only the white and yellow clays, but likewise the blue, the soft, the hard, the laminated, &c., which I consider to be the scoriæ of glass, or the decompositions of

glass*. By *sand*, I always understand vitrifiable sand; and I comprehend, under this denomination, not only the fine sand, which produces free-stone, and which I maintain to be the powder of glass, or rather of tufa, but also that sand rubbed off free-stone, and the still grosser kind resembling small gravel, proceeding from granite and rock-stone, and which is brittle, angular, and reddish, and generally found in the beds of those rivers which descend precipitantly from hills or mountains composed of granite or common rock. The river Armanson, which runs by Semer in Auxois, where all the stones are of common rock, carries down great quantities of this gross, rough, and brittle sand. It is of the same nature with rock-stone, of which it is only small portions, as calcinable gravels are only particles of free-stone. Besides, rock-stone and granite are the same substances; but I have used both terms, because they are considered by some as different species. The same may be remarked of flints and of free-stone in large masses: these also are species of granite; and I call them flints in large masses, because, like calcinable stones, they are disposed in beds, and also to distinguish them from flints and free-stone in small masses, as the round flints and sand-stones, which have no continuation, or are not found in beds of any extent. These are recent productions, and have not the same origin

* Glass being composed of an alkali with silica, cannot properly be ranked among the clays. W.

as flint and free-stone in large masses, which form regular and extensive strata. Under *slate* I comprehend the blue, the white, the gray, the reddish, and all the plated stones. These bodies are generally found below laminated clay, and seem to be nothing else but clay hardened into thin strata by drying; and this is the reason of so many cracks or fissures remarkable in such substances. Coal and jet are likewise referable to clay, and are found under the laminated clays or slate. By *tufa*, I mean not only the common pumice, which is full of holes, and has an organized appearance, but all beds of stone formed by the sediments of running waters, all the stalactites, incrustations, and every kind of stone that dissolves by fire. It does not admit of a doubt that all these are new substances, and that they are constantly growing. Tufa is only a mass of stony matter, not distinguished by regular strata. This matter is commonly found in small hollow cylinders, irregularly grouped, formed by rills or percalations at the foot or upon the declivities of hills, and consisting of coats of marl or calcareous earth. The cylindric form is the specific character of this kind of tufa, and it is always either oblique or straight, according to the direction of the rills by which it is produced. The extent of these spurious quarries is inconsiderable, and generally proportioned to the height of the mountains which furnish the materials of their growth. The intervals between the cylinders of the tufa, by the daily addition of fresh stony matter, are at last filled up,

and the whole assumes a compact and solid form; but it never acquires the hardness of stone, and, for that reason, is denominated by Agricola, *marga tofacea fistulosa.* In the tufa are often found impressions of the leaves of such trees and plants as grow in the neighbourhood; land shells, well preserved, are likewise frequently found in the tufa, but never sea shells; it is, therefore, a recent production, and ought to be ranked with stalactites, incrustations, &c. All these new substances are a kind of spurious stones, formed by the wasting of others, but never arrive at the consistence of real petrifaction.

Crystal, precious stones, every stone that has a regular figure, and even flints in small masses, and consisting of concentric coats, whether found in the perpendicular fissures of rocks, or elsewhere, are only exudations, or the concreting juices of flint in large masses; they are, therefore, new and spurious productions, the genuine stalactites of flint or of granite.

Shells are never found in common rock or granite, nor in free-stone, although they often appear in vitrifiable sand, from which free-stone derives its origin. This circumstance seems to indicate, that sand, unless when perfectly pure, cannot unite into free-stone or granite; and that a mixture of shells, or of other heterogeneous bodies, totally prevents it from cementing. I have often examined those small round stones, found in beds of sand, which are mixed with shells, and never could discover in them a single shell. These round stones are true concretions

of free-stone, formed in those places where the sand is pure, and not mixed with heterogeneous matter; which is the reason why no larger masses are produced.

We formerly remarked, that, at Amsterdam, which is a very low country, sea shells were found 100 feet below the surface, and at Marly-la-Ville, 6 leagues from Paris, at the depth of 75 feet. They have also been found in mines below beds of rock of 50, 100, 200, and even of 1,000 feet thick, as is apparent in the Alps and Pyrennees, where shells and other sea bodies are found in the inferior strata of immense rocks, which have been cut through in a perpendicular direction. But to proceed in order: Shells are found in the mountains of Spain, France, and England, in all the marble quarries of Flanders, in the mountains of Gueldres, in all the hills round Paris, in those of Burgundy and Champagne; in a word, in all places where the basis is not composed of free-stone or tufa; and, in all these places, the substance of the stones consists more of shells than of any other matter. By shells, I mean not only the remains of shell-fish, but likewise those of crustaceous animals, the bristles of sea hedge-hogs, and all the productions of sea insects, as corals, madrepores, astroites, &c. Any man may be convinced, by the evidence of his own eyes, that, in most marbles and calcinable stones, the proportion of sea bodies is so great, as to exceed the matter by which they are united.

But farther, sea bodies are found even on the

tops of the highest mountains of the Alps; for example, on the top of Mount Cenis, in the mountains of Genes, in the Appennines, and in most of the stone and marble quarries of Italy. They appear in the stones of which the most ancient buildings in Rome are constructed, in the mountains of Tirol, in the centre of Italy, on the top of Mount Paterne, near Boulonge, in the hills of Pouille, in those of Calabria, in many parts of Germany and of Hungary, and, lastly, in all the high grounds of Europe *.

In Asia and Africa, travellers have observed sea shells in several places; for example, "upon the Castravan mountains, above Baruth," says Shaw †, "where there is a curious bed of whitish stone, but of the slate kind, which contains, in every flake of it, a great number and variety of fishes. These, for the most part, lie exceedingly flat and compressed, like the fossil fern plants; yet, at the same time, they are so well preserved, that the smallest strokes and lineaments of their fins, scales, and other superficial diversities, are easily distinguished." Between Cairo and Suez, and particularly upon all the hills of Barbary, says the same author, are many petrified shells and echini; most of them exactly correspond with the different species still existing in the Red Sea. As to Europe, petrified fishes are to be met with in Switzerland, Germany, the quarry of Oningen, &c.

* See Steno, Ray, Woodward, &c.

† See Shaw's Travels, p. 341.

Fossil shells, says M. Bourguet, are to be found in the long chain of mountains stretching from Portugal to the most easterly parts of China, in the valleys of Europe, and in all the mountains of Africa and America; and hence, he remarks, we may conclude, that they also exist in those parts of the globe with which we are still unacquainted.

The islands of Europe, of Asia, and of America, wherever men have had occasion to dig, whether in the mountains or in the valleys, furnish many specimens of fossil shells; and this circumstance demonstrates, that islands are analogous in structure and formation to their neighbouring continents *.

These facts are sufficient to prove, that fossil shells, petrified fishes, and other productions of the ocean, exist in great quantities in almost every place where proper investigations have been made. "It is true," says Tancrid Robinson, "that sea shells are dispersed occasionally on the earth by armies, and by the inhabitants of towns and villages. La Loubere relates, in his voyage to Siam, that the monkeys of the Cape of Good Hope perpetually amuse themselves by transporting shells from the shores of the sea to the tops of the mountains. But this is no solution to the question, why these shells are dispersed through every climate of the earth, or why they are found in the bowels of the highest

* See Lettres philosoph. sur la Formation de Sels, p. 205.

mountains, and disposed in beds, like those in the bottom of the ocean."

Upon perusing an Italian letter, printed at Paris in the year 1746, concerning the changes this globe has undergone, I was astonished to find a repetition of Loubere's sentiments. Petrified fishes, in the opinion of this writer, are always of rare species, which were rejected from the Roman tables, because they were not esteemed to be wholesome: and as to fossil shells, he says, that the pilgrims brought from Syria, in the time of the crusades, those shells peculiar to the Levant, which are now found petrified in France, in Italy, and in other parts of Christendom. Why did he not add, that the monkeys transported shells to the tops of the highest mountains, which never were inhabited by men? This he might have done with great facility, and it would have given an air of credibility to his hypothesis! How should men, who pretend to philosophy, differ so widely in their opinions? It is not sufficient, it would appear, to find fossil shells in almost every part of the earth where pits have been dug, nor to have quoted the testimonies of natural historians, as these authors may, according to certain systems, have imagined that shells existed where none were to be found: we shall therefore, to prevent all prejudices of this kind, quote the authority of some authors who had no theory to support, and whose habits of observation could only enable them to recognise shells that were entire, and in

the best preservation. This testimony will, perhaps, have greater authority with men who cannot judge of the facts, nor know the distinction between real shells and their petrifactions *.

* I find that I have not treated M. de Voltaire with sufficient respect. I acknowledge, that I should rather have taken no notice of this opinion, than revived it with a jest, especially as humour is not my talent, and as this is perhaps the only example of pleasantry in all my works. M. de Voltaire is a man whose superiority of genius merits * the highest regard. I was furnished with this letter at the very time I was correcting the sheet which contains the passage in question. I read part of it only, imagining it to be the production of some learned Italian, who, from mere historical knowledge, had followed his own prejudices, without consulting Nature; and it was not till after my volume on the Theory of the Earth was printed, that I knew the letter was written by M. de Voltaire. I then sincerely regretted the expressions I had used. This truth I thought it incumbent on me to make public, as well for the sake of M. de Voltaire, as for my own and that of posterity, to whom I would not leave a doubt of the high esteem I have always had for a man of such uncommon talents, and who has done so much honour to human nature and to the age in which he lived.

As the authority of M. de Voltaire made an impression upon some persons, others have endeavoured to discover whether his objection, with regard to the shells found below ground, has any foundation. Upon this subject, I shall subjoin an extract of a memoir, which was transmitted to me, and which appears to have been written with that intention.

In traversing the different provinces of France, and even of Italy, "I every where saw," le P. Chabenat remarks, "figured stones; and, in particular places, their number was so great, and they were arranged in such a manner, that it was impossible not to be satisfied, that these parts of the earth had formerly been covered by the sea. I saw shells of

* This apology was published in the year 1778.

Every man may examine with his eyes the banks of shells in the hills round Paris, and especially in the stone-quarries, as at Chaussée

every kind, which were perfectly similar both in figure and size, to those which now exist. This observation was sufficient to convince me, that all these individuals were of different ages, but of the same species. I saw cornua ammonis from half an inch to near three feet in diameter. I saw cockles of all sizes, as well as other bivalves and univalves. I likewise saw belemnites, sea mushrooms, &c.

"The form and number of these figured stones prove, in the most incontestible manner, that they were formerly animals which existed in the ocean. The shells with which the moulds are covered seem to remove every doubt upon this subject, for, in particular specimens, it is equally lustrous, fresh, and natural, as in the living animal. If separated from the mould or nucleus, we could not believe that it was petrified. The same observation is applicable to many other figured stones found in that beautiful and extensive plain, which stretches from Mountauban to Toulouse, and from Toulouse to Alby, as well as to the circumjacent places. The whole of this vast plain is covered with vegetable soil from half a foot to two feet thick. Below the soil there is a bed of coarse gravel about two feet in thickness. The gravel is succeeded by a bed of fine sand, which is nearly of an equal thickness; and the rock lies immediately under this bed of sand. I have repeatedly examined the gravel with the greatest attention, and I found it interspersed with an infinite number of figured stones of the same form, but of various sizes. I likewise found a number of sea hedge-hogs, and other stones of a regular figure, and perfectly similar. All these facts announce, in language the most expressive, that this country, as well as many others, had formerly been the bottom of the sea, which, by some sudden revolution, had retired and left its various productions behind. I shall, however suspend my judgment, on account of M. de Voltaire's objections, to remove which, experience and observation must be united."

Le P. Chabenat next subjoins several experiments, to

near Seve, at Issy, Passy, and other places. A great quantity of lenticular stones are to be found at Villers-Cotterets; the rocks are almost entirely composed of these stones; and they are irregularly interspersed with a kind of cement, by which they are united. At Chaumont, the quantity of shells is so great, that the whole hills, which are pretty high, appear to consist of nothing else. The same phænomenon is exhibited at Courtagnon near Rheims, where there is a bank of shells of about four leagues broad, and the length is still more considerable. I mention these places, because they are famous, and the shells strike the eye of every beholder.

With regard to foreign countries, let us attend to the remarks of travellers.

" In Syria and Phœnicia, in the neighbourhood particularly of Latikea, the rocks are of a hard chalky substance, from whence the adjacent city might borrow the name of the *White*

prove that the shells found in the earth are the same with those which still exist in the sea. These experiments I shall not relate, because they contain nothing new; and every man is satisfied, that fossil and marine shells are precisely of the same nature. Le P. Chabenat concludes his Memoir with remarking, that " all the shells found in the bowels of the earth are unquestionably real shells, and relics of animals whose element is the ocean, which had formerly covered these countries; and, consequently, that the objections of M. de Voltaire are ill founded *."

* Memoir Manuscrit sur les Pierres Figurées, par le P. Chabenat, Mountauban, Oct. 8. 1773.

Promontory. The Nakoura, formerly called the *Scala Tyriorum*, is of the same nature and complexion; both of them including a great variety of corals, shells, and other remains of the deluge*."

"But fossil shells, and other the like testimonies of the deluge, are very rare in the mountains near Sinai, the original menstruum, perhaps, of these marbles, being too corrosive to preserve them. Yet, at Corondel, where the rocks approach nearer to our free-stone, I found a few chamæ and pectunculi, and a curious echinus of the discoid kind. The ruins of the small village at Ain-el-Mousa, and the several conveyances we have there for water, are all of them full of fossil shells. The old walls of Suez, and the remains that are left us of its harbour, are likewise of the same materials, all of them probably from the same quarry. Between Suez and Cairo, likewise, and all over the mountains of Lybia, near Egypt, every little rising ground and hillock discovers great quantities of the echini, as well as of the bivalve and turbinated shells, most of which exactly correspond with their respective families still preserved in the Red Sea*."

The moving sand in the neighbourhood of Raz Sem, in the kingdom of Barca, covers many palm-trees, echini, and other petrifactions. *Raz Seme* signifies *the head of a fish*, and is the name

* See Shaw's Travels, p. 344. † Ibid. p. 444.

of what is called the petrified village, where it has been alleged, that men and women, with their children, cattle, furniture, &c., may be seen converted into stone. " But," says Mr. Shaw, " all this is mere fiction, as I learned not only from Mr. Mair, consul at Tripoli, who sent several people to examine into the fact, but also from men of credit and learning who had been on the spot."

Near the Pyramids Mr. Shaw discovered some stones which had been hewn by workmen; and were mixed with little round bodies like lentils, and some of them resembled barley half peeled. " These," he says, " were supposed to have been fragments of victuals left by the workmen, and are now petrified. But this account appears to be very improbable," &c. These lentils and grains of barley are nothing but petrified shells, known to every naturalist by the name of lentil-stones.

" Many fossil stones," says Misson *, " are found in the neighbourhood of Maestricht, especially near the village of Zichen or Tichen, and in the mountain called the *Huns*.

" In the environs of Sienne, near Certaldo, are many mountains of sand filled with different kinds of shells. Monte-mario, about a mile from Rome, is also full of them. I have remarked them in the Alps, in France, and in other places. Orlearius, Steno, Cambden, Speed,

* See Voyage de Misson, tom. iii. p. 109.

and many other writers, have related the same phænomena*."

"The island of Cerigo," says Thevenot†, "was called *Porphyris* by the ancients, on account of the quantities of porphyry found in it." Now, porphyry, as observed above, is composed of the prickles of the echinus, or sea hedge-hog, united by a very hard stony cement.

"Opposite to Inchené, a village on the east bank of the Nile, I found petrified plants growing naturally on a piece of ground about two leagues in length, and of an inconsiderable breadth. This is one of the most singular productions in nature. The plants resembled the white corals which grow in the Red Sea‡."

"There are several species of petrifaction on Mount Libanus, and, among others, flat stones, which contain the skeletons of fishes entire, and well preserved; chesnuts, and small branches of coral, of the same species with what grows in the Red Sea, are likewise found on this mountain§."

"In Mount Carmel," says Shaw, "we gather a great many hollow stones, lined in their insides with a variety of sparry matter, which, from some distant resemblance, are said to be petrified olives, melons, peaches, and other fruit. These are commonly bestowed upon pilgrims,

* See Voyage de Misson, tom. ii. p. 312.

† Voyage de Thevenot, tom. i. p. 25.

‡ See Voyage de Paul Lucas, tom. ii. p. 380.

§ Ibid. tom. iii. p. 326.

not only as curiosities, but as antidotes against several distempers: the olives, which are *lapides Judaici*, as they are commonly called, have been always looked upon, when dissolved in the juice of lemons, as an approved medicine against the stone and gravel*." These *lapides Judaici* are the points of the echinus.

" M. la Roche, a physician, gave me some petrified olives, called *lapides Judaici*, which grow in great quantities upon the mountains, where are to be found, according to my information, other stones, which in their inside contain perfect representations of the natural parts of men and women†. These are the hysterolithes."

" In going from Smyrna to Tauris," says Tavernier, " when we came to Tocat, the heat was excessive; we therefore left the common road to the north of us, and went by the mountains, where there are always shade and cool breezes. In many places we found snow; and, upon the tops of some of these mountains, we saw shells resembling those upon the sea-shore, which is an extraordinary phænomenon."

Let us attend to what Olearius says concerning the petrified shells he observed in Persia, and in the rocks where the sepulchres have been cut near the village Pyrmarus.

" Three of us ascended, by mutually assisting each other, the most frightful precipices, and at last gained the summit, where we found four

* See Shaw's Travels, p. 444.

† Voyag. de Monconys, p. 331.

large chambers, with several niches cut out of the solid rock: but what struck us most was, to find in this vault, on the top of the mountain, muscle shells; and in some parts they appeared in such quantities, that this whole rock seemed to consist of nothing but sand and shells. In returning from Persia, we perceived several of these shelly mountains upon the coasts of the Caspian Sea."

To the enumeration I have given of the great quantities of shells found in all parts of the world, I might add many particular observations which have been since communicated to me. I have received letters from the American islands, by which I am assured that, in almost all of them, shells are found, either petrified or in their natural state, in the interior parts of the earth, and often below the first stratum or vegetable soil. In the Malouine islands, M. de Bougainville found stones which divided into thin plates or leaves, and upon which were impressions of fossil shells, of a species unknown in these seas*. To the same purpose I have letters from several parts of India and of Africa. Don Ulloa informs us†, that, in that district of Chili which extends from Talca Guano to Conception, different kinds of shells are found in great numbers, and without any mixture of earth; and that these shells are used to make lime. He adds, that this peculiarity would not be so remarkable, if these shells were found only in low

* Voyage Autour du Monde, tom. i. p. 100.

places, which might be covered with the sea. But what is singular, he remarks, that the same heaps of shells are found in the hills at the height of fifty fathoms above the level of the sea. I relate this fact, not because it is singular, but because it corresponds with all the others, and is the only one known to me concerning fossil shells in this part of the world, where I am persuaded that petrified shells will be found, as well as every where else, at heights much greater than fifty fathoms above the level of the sea; for the same Don Ulloa has since found petrified shells in the mountains of Peru, at the height of above 2,000 fathoms; and, according to M. Kalm, shells are seen in North America upon the tops of several hills: he tells us, that he saw them on the summit of the Blue Mountains. They have also been found in the chalk quarries near Montreal, in certain stones near Lake Champlain in Canada*, and in the most northern regions of this New Continent; for the Greenlanders believe, that the world had been drowned by a deluge, and, in evidence of this event, they quote the shells and the bones of whales which cover the most elevated mountains of their country †.

If from this we pass to Siberia, we shall find the same proof of the ancient abode of the ocean upon all our Continents. Near the mountain Jeniseik, there are other mountains less ele-

* Mem. de l'Acad. des Sciences, ann. 1752, p. 194.

† Voyage de M. Crantz; Hist. Gen. des Voyages, tom. xix. p. 105.

vated, upon the summits of which we find heaps of shells well preserved both in figure and natural colours. These shells are all empty, and some of them fall into powder as soon as they are touched. *The sea of this country produces no shells similar to those found on the tops of mountains.* The largest of these shells exceed not an inch in breadth, and others are very small*.

But I can exhibit facts which are still more obvious. Every man, in his own province, has only to open his eyes, and he will see shells in all places where lime-stone is found, as also in most clays, though, in general, marine productions are more rare in clays than in calcareous substances.

In the territory of Dunkirk, on the top of the mountain of the Recollets, near that of Cassel, and at 400 feet above the level of the sea, there is a horizontal stratum of shells, which are so closely packed together that most of them are broken. Above this stratum there is a bed of earth from seven to eight feet deep. These shells are situated at the distance of six leagues from the sea, and they are of the same species with those found on its coast†.

In Mount Gannelon, near Anet, and at some distance from Compiegne, there are several quarries of excellent lime-stone. Between the

* Relation de Mess. Gmelin et Muller; Hist. Gen. des Voyages, tom. xviii. p. 342.

† Mem. pour la Subdelegation de Dunkerque, relative de ce Canton.

different strata of the lime-stone we find gravel mixed with an infinite number of sea shells, or portions of shells, which are very light and friable. In the same place, there are common oyster shells in fine preservation, and extend more than a league and a quarter in length. In one of these quarries, there are three strata of shells in different states. In two of these strata, they are so much broke, that their species cannot be distinguished: but, in the third, there are oysters, which have suffered no alteration, but that of being excessively dried. The nature, figure, and enamel of the shells, are the same as in the live animals. These shells have acquired a great lightness, and easily exfoliate. The lime-stone quarries are situated at the foot of the mountain, and have a small declivity. In descending towards the plain, we find oysters, which are neither dried, nor have undergone any change, but have the same weight, and the same enamel with those which are daily taken out of the sea*.

In the neighbourhood of Paris, these marine shells are not less common. The marl pits of Bougival furnish a kind of middle-sized oysters. They are not entire, but cut in different directions, and finely polished. Near Belleville, where free-stone is quarried, we find a mass of sand in the earth, which contains branched bodies,

* Extrait d'une Lettre de M. Leschevin à M. de Buffon; Compiegne, Oct. 8, 1772.

which may have been corals or madrepores converted into stone. These marine bodies are not in the sand alone, but in the stones, which likewise contain shells of different kinds, as volutes, univalves, and bivalves*.

Switzerland is not less abundant in fossil marine bodies than France and the other countries we have mentioned. In Mount Pilate, in the canton of Lucerne, we find petrified sea shells, and the bodies and relics of fishes. In the same mountain, there are corals, and slates which easily exfoliate, and, between the leaves, a fish is generally found. Some years ago, the jaws, and even entire heads of fishes, together with their teeth, were discovered†.

M. Altman remarks, that, in one of the highest parts of the Alps, near Grindelvald, where the famous glaciers (Gletchers) are formed, there are fine marble quarries, which he has represented in one of the engravings of these mountains. The marble quarries are only a few paces distant from the glaciers. The marble is of various colours, as white, yellow, jasper, red, and green. The marble is drawn on sledges above the snow as far as Underseen, where it is embarked to be carried to Berne by Lake Thorne, and afterwards by the river Are‡.

* Mem. de M. Guettard; Acad. des Sciences, ann. 1764, p. 492.

† Promenade au Mont Pilate; Journal Etrangers, mois de Mars, 1756.

‡ Essai de la Description des Alps Glaciales, par M. Altman.

Thus marble and calcareous stones are found, at great heights, in this part of the Alps.

M. Cappeler, in making researches on Mount Grimsel, one of the Alps, has remarked, that the hills and smaller mountains which limit the valleys, are mostly composed of free-stone, of a grain more or less fine and close. The tops of these mountains generally consist of limestone, of various colours and hardness. The mountains more elevated than these calcareous rocks, are composed of granite and other stones, which appear to be of the nature of granite and of emery. It is in these granity stones that rock crystal begins to be formed. But, in the limestone rocks below, we find nothing but spar and calcareous concretions. In general, it has been remarked, concerning shells of every kind, whether fossil or petrified, that certain species are always found together, and that others are never met with in these places. The same thing happens in the ocean, where particular species of testaceous animals are constantly found together, in the same manner as certain plants always grow together on the surface of the earth*.

It has been too generally believed, that there are no shells or other productions of the sea, on the highest mountains. It is true, that there are several summits, and a great number of peaks, which are entirely composed of granite and vitrifiable rocks, in which no mixture can be per-

* Lettres Philosophiques de M. Bourguet, Bilioth Raisonneé, mois d'Avril, Mai, Juin, 1730.

ceived. These contain neither the moulds of shells, nor the relics of any marine bodies. But there is a much greater number of mountains, and some of them very high, where these relics are to be found. M. Costa, professor of anatomy and botany in the university of Perpignan, in the year 1774, discovered, some fathoms below the top of Mount Nas, situated in the middle of the Spanish Cerdagne, and one of the most elevated parts of the Pyrennees, a great number of lenticular stones, *i. e.* blocks composed of lenticular stones, and these blocks were of different figures and different sizes; the largest might weigh from forty to fifty pounds. He remarked, that the part of the mountain where these lenticular stones were found, seemed to have formerly sunk; for, in this place, he saw an irregular, oblique depression, very much inclined to the horizon; and one of its extremities respected the top, and the other the bottom of the mountain. He could not distinctly perceive the dimensions of this depression, because most of it was covered with snow, though it was the month of August. The banks of rocks, which surrounded these lenticular stones, as well as those immediately below, are calcareous for more than a hundred fathoms. This Mount Nas, to judge of it by the eye, seems to be as high as Canigou, and presents no vestige of a volcano.

A thousand other examples of marine shells, found in an infinity of places, as well in France as in different parts of Europe, might be given.

which are already too much multiplied, would swell this work, without answering any useful purpose. From the whole, however, we cannot refrain from drawing this obvious conclusion, that all the inhabited parts of the earth have formerly, and during a very long course of time, been covered with the waters of the ocean.

I shall only remark, that these sea shells are found in different states. Some of them are petrifactions, or stones moulded into the form of shells; and others are in the same state as they still exist in the ocean. The quantity of petrified shells, which are nothing but stones figured by shells, is infinitely greater than that of fossil shells, and they are never found together, nor even in places contiguous: it is only in the neighbourhood, and some leagues distant from the sea, that we find beds of shells in their natural state, and these are commonly the same with those which exist in the adjacent seas. Petrified shells, on the contrary, are found, almost every where, at great distances from the sea, and on the highest hills, many species of which belong not to our seas, and several of them have no existing representatives; such as those ancient species we formerly mentioned, which only existed when the globe was much warmer. Of more than a hundred species of cornua ammonis, remarks one of our learned Academicians, with which we are acquainted, and which are found in the environs of Paris, of Rouen, of Pive, of Langres, and of Lyons, as

well as in the Cevernes, in Provence, in Poitou, in Britain, in Spain, and in other countries of Europe, there is but one species, called the *Nautilus papyraceus*, found in our seas, and five or six others produced in foreign seas *.

In France, we find not only the shells belonging to our own coasts, but those which never appeared in our seas. Some philosophers even allege, that the number of foreign petrified shells greatly exceeds those of our own climate. But this opinion seems not to be well founded; for, independent of such shells as lie in the bottom of deep water, and are seldom brought up by fishers, and, of course, are regarded by us as foreigners, though they may exist in our seas, I find, upon comparison, that more of the petrified shells belong to our own shores than to any other. For example, all the pectines, most cockles, muscles, oysters, trumpet-shells, ear-shells, limpets, nautili, stars, tubulites, corals, madrepores, &c., which are found so universally, are really produced in our seas: and, though many sea bodies appear, which are either foreign or unknown, as the cornu ammonis, the lapides Judaici, the large screw, the buccinum, called *abajour*, &c., yet I am convinced, by repeated observation, that the number of these species is inconsiderable, when compared with the shells which belong to our own coasts. Besides, the madrepores, astroites, and all those sea bodies formed by insects, constitute the basis of our

* Mem. de l'Acad. des Sciences, ann. 1722, p. 242.

marbles and lime-stone; for the shells, however abundant, make but a small part of these stones, and many of them are produced in our own seas, and particularly in the Mediterranean.

The Red Sea produces corals, madrepores, and sea plants, more abundantly than any other. The port of Tor furnishes an amazing quantity. In calm weather, the quantity exhibited is so great, that the bottom of the sea resembles a forest. Some of the branched madrepores rise from eight to ten feet high. They are also very common in different parts of the Mediterranean, and are to be found in all gulfs, islands, &c., of every temperate climate, where the sea is not very deep.

Mr. Peyssonel was the first who discovered that coral, madrepores, &c., were not plants, but that they derived their origin from animals. The truth of this discovery was long doubted. Some naturalists at first rejected it with disdain. But it soon gained universal assent; and every man is now satisfied, that what were formerly called sea plants, are nothing but hives, or rather lodges, formed by insects for their own habitation. These bodies were originally classed with minerals, then with plants, and now they must for ever be recognised as the genuine operation of animals.

Many shell-fish inhabit the deepest parts of the ocean, and are never thrown upon the coasts; authors have, therefore, termed them *Pelagiæ*, to distinguish them from the other kinds, which they call *Littorales*. It is proba-

ble that the cornu ammonis, and some other species, found only in a petrified state, belong to *the former*, and that they have been impregnated with stony matter in the very places where they are discovered. *It is also probable*, that the species of some animals have been extinguished, and that these shells may be ranked among their number. The extraordinary fossil bones found in Siberia, in Canada, in Ireland, and several other places, seem to confirm this conjecture; for no animal has hitherto been discovered to whom bones of such enormous size could possibly belong.

Upon this passage I have to make two important remarks.

1. That these cornua ammonis, which are so different from each other both in figure and size, seeming to form rather a genus than a species in the class of shell animals, are really the relics of so many species which have perished, and no longer subsist. I have seen some of them so small, that they exceed not a line, and others so large that they were more than three feet in diameter. Observers worthy of credit, have assured me that they have seen some still larger, and particularly one of eight feet in diameter and one foot thick. These different cornua ammonis seem to form distinct species. Some of them are more or less fluted. They are all spiral; but they terminate differently, both at their centres and at their extremities. These animals, formerly so numerous, are no longer found in any of our seas. They are

known to us by their relics only; and the immensity of their number cannot be better represented than by an example which I have daily before my eyes. In the iron mine near Etivey (three leagues from my forge of Buffon), which has been wrought 150 years, and has supplied the iron works of Aisy during all that time, there are such quantities of cornua ammonis, entire and in fragments, that the greatest part of the ore seems to have been moulded in these shells. The mine of Conflans in Lorrain, which supplies the furnace of Saint Loup in Franche-comte, is likewise entirely composed of belemnites and cornua ammonis. These last ferruginous shells are so different in size, that they weigh from a drachm to two hundred pounds *. Other places might be mentioned where they equally abound. In the same manner, we find belemnites, lenticular stones, and moulds of many other shells, which now no longer exist in any part of the ocean, though they are almost universally diffused over the surface of the earth. I am persuaded that all these lost species formerly subsisted during the time that the temperature of the earth and waters was warmer than it is at present; and that, in proportion as the globe cools, other species, which now exist, will perish like the former, for want of heat sufficient to support them.

2. That some of those enormous bones, which I thought had belonged to unknown animals,

* *Mem. de Physique de M. Grignon, p. 378.*

whose species was supposed to be lost, have nevertheless, after the most accurate examination, appeared to belong to the elephant and hippopotamus, but to species of these animals much larger than those which now exist. Of land animals I know only one species which is lost; and it is that of the animals whose grinding teeth, with their just dimensions, are represented in plates iii. iv. v. The other large teeth and bones, which I have collected, belonged to the elephant and hippopotamus.

Fossil shells, says Woodward, are found from the top to the bottom of quarries, in pits, and in the deepest mines of Hungary: and we are informed by Mr. Ray, that they are found in the rocks on the shores of Calda, and in Pembrokeshire, at the depth of 200 fathoms *.

Shells not only appear in a petrified state at great depths, and on the tops of the highest mountains, but they are also found in their natural condition, having the colour, lustre, and lightness of sea shells; so that, to be fully satisfied on this subject, nothing farther is requisite than to compare them with the shells found on the shores of the sea. The slightest examination will convince us, that petrified and fossil shells are precisely the same with those of the ocean; for they are marked with the same furrows and articulations, however minute; and, in the glossopetri and other teeth of fishes, which are sometimes found adhering to the jaw-bone,

* See Ray's *Discourses*, p. 178.

it is obvious, that the teeth are worn and polished at the extremities, and that they have been used by the living animals.

Fossil shells are almost every where to be met with; and, of those of the same species, some are small, others large, some young, others old, some entire, others imperfect; and sometimes young ones appear adhering to the old.

The shell-fish called *Purpura* has a long tongue, the extremity of which is so sharp and osseous, that it pierces the shells of other fishes, in order to extract nourishment from them. Shells pierced in this manner are often found in the bowels of the earth; which is an incontestible proof that they were formerly inhabited by living fishes, and that they existed in the same places with the purpura *.

The obelisks of St. Peter's at Rome, according to John of Latran, were said to have been brought from the Egyptian pyramids: they consist of a red granite, which, as formerly remarked, contains no shells. But the ancient marbles of Africa and Egypt, and the porphyry said to have been brought from Solomon's Temple, and the palaces of the Egyptian kings, and employed in several of the Roman buildings, are full of shells. Red porphyry is composed of an infinite number of the prickles of that species of echinus called a sea chesnut; they are placed very near each other, and form the white points of the porphyry. Each of these

* See Woodward, p. 296, 300.

points has a black speck in the middle, which is the section of the longitudinal tube of the prickle of the echinus. At Ficin in Burgundy, three leagues from Dijon, there is a red stone so similar to porphyry, that it differs only in density, not being harder than marble: it is entirely composed of the points or prickles of the echini, and the stratum of it is considerable both in thickness and extent. Many excellent pieces of workmanship are made of it in this province, and particularly the steps which lead to the pedestal of the equestrian statue of Louis le Grand, at Dijon. This species of stone is also found in Montbard in Burgundy; it is softer than marble; but it contains still more prickles of the echini, and a smaller proportion of red matter. Thus the ancient porphyry of Egypt, and the porphyry of Burgundy, differ only in the degree of hardness, and in the quantity of prickles or points of the echinus contained in them.

With regard to what is called green porphyry, I imagine it to be rather a granite than a porphyry. It is not, like the red porphyry, composed of the prickles of the echinus; and its substance has a greater resemblance to that of common granite. The ancient walls of Volatera in Tuscany have been built of stones in which are many shells, and these walls were erected 2,500 years ago *. Most marbles, porphyries, and other stones employed in the buildings of the ancients, contain shells and other

productions of the ocean, in the same manner as some of our modern marbles. Hence we may conclude, that, independent of the testimony of holy writ, the earth, before the deluge, was composed of the same materials as at present.

Upon the whole, it is apparent, that petrified shells are found in Europe, in Asia, in Africa, and in every place where proper researches have been made. They are also found in America, in the Brasils, for example, in Tucumana, in Terra Magellanica, and in such vast quantities in the Antilles, that what the inhabitants call lime, which lies immediately below the soil, is nothing but a congeries of shells, corals, madrepores, astroites, and other sea bodies. These incontestible facts would have led me to conclude, that petrified shells, and other productions of the ocean, were to be found through the whole continent of America, and especially in the mountains, as Woodward affirms. But M. de la Condamine, who lived several years in Peru, assures me, that he was never able to discover any of them in the Cordeliers, although he had diligently searched for them. This phænomenon would indeed be singular, and would lead to conclusions still more uncommon. But, I confess, the testimony of this celebrated observer notwithstanding, I am strongly inclined to believe that there are, in the mountains of Peru, as well as every where else, petrified shells and other *sea bodies, although they have not yet been discovered.* In matters which depend on testimony, the positive evidence of two witnesses is a com-

plete proof; but the evidence of ten thousand witnesses, who only declare in the negative, that they never observed a particular appearance, gives rise to nothing more than a slight doubt. Thus reason, joined to the force of a general analogy, obliges me to persist in believing that fossil shells will still be found in the mountains of Peru, especially if they are searched for in the sides, and not on the very summits.

The tops of high mountains are generally composed of granite, free-stone, and other vitrifiable materials, which never contain shells. These matters were all formed out of beds of sand, when they were covered by the sea. But, when the waters left the mountains, they would carry off the sand, and other light bodies, into the plains, and leave nothing on their tops but those beds of rock which had been formed below the stratum of sand. At two, three, or four hundred fathoms below the summit of these mountains, we often find marbles and other calcinable matters, disposed in parallel beds, and containing shells and other sea bodies. Hence, if M. de la Condamine examined only the most elevated places, which consist of granite, of freestone, or of vitrifiable sand, it is not surprising that he did not find fossil shells. But he ought to have explored the lower parts of the Cordeliers, and he would unquestionably have discovered beds of marble, earth, &c., mixed with shells; for such beds have been found in every part of the world that has undergone a proper

But, supposing it to be a fact, that there are no productions of the ocean in the mountains of Peru, nothing could be concluded from it which could affect our theory. Some parts of the globe, and particularly places of such elevation as the Cordeliers, might never have been covered with the sea. These mountains, however, would be an ample field for curious observation. They would not, in that case, consist of parallel beds. Their materials would be very different from all others: they would have no perpendicular fissures: the structure of the stones and rocks would have no resemblance to those of other countries: *lastly*, These mountains would exhibit the ancient structure of the earth before it was changed by the motion of the waters; they would discover the primitive state of the globe, its original form, the natural arrangement and connexion of its parts. But this notion is supported by too slender a foundation; and it is more consonant to the rules of philosophy to believe that fossil shells exist in the mountains of Peru, in the same manner as they exist every where else.

With regard to the position of shells in beds of earth or of stone, let us attend to the following passage of Woodward: "All the shells that are found in numberless strata of earth, and rocks, in the highest mountains, and in the most profound quarries and mines, in flint, cornelian, agate, &c., and in masses of sulphur, marcasites, and other mineral and metallic bodies, are filled with the same substances that compose the strata

in which they are included, and never with any heterogeneous matter;" p. 206, &c.——"We now find in the sand-stone of all countries (the specific gravity of the several sorts whereof is very little different, being generally to water as $2\frac{1}{2}$ or $\frac{9}{10}$ to 1), only those conchæ, pectines, cochleæ, and other shells that are nearly of the same gravity, *viz.* $2\frac{1}{2}$ or $2\frac{5}{8}$ to 1. But there are ordinarily found enclosed in it prodigious numbers; whereas, of oyster shells (which are in gravity but as about $2\frac{1}{3}$ to 1), of echini (which are but as 2 or $2\frac{1}{8}$ to 1), or the other lighter kinds of shells, scarce one ever appears therein. On the contrary, in chalk (which is lighter than stone, being but as about $2\frac{1}{10}$ to 1) there are only found echini, and the other lighter sorts of shells;" p. 32, 33.

It must here be remarked, that what Woodward says with respect to specific gravity, is not universally true; for shells of different specific gravities are often found in the same matters; shells of cockles, of oysters, and of echini, for example, are found in the same bed of stones or of earth. In the cabinet of the French king, there is a cockle petrified in a cornelian, and echini petrified in an agate. Hence the difference in the specific gravity of shells has had less influence upon their position in the strata of the earth than Woodward would have us to believe. The reason why the shells of the echini, and others of a light texture, abound so much in chalk, is owing to this circumstance, that chalk itself is only decomposed shells; those of the echini being lighter and thinner than others,

would be most easily reduced to powder or chalk; and hence beds of chalk could exist only in those places where were formerly collected by the sea great quantities of light shells, the destruction of which would form that chalk in which we still find shells that have resisted the operation of time, either in an entire state, or in fragments sufficient to discover their species.

This subject shall be more fully treated of in the article concerning minerals. I shall here only observe, that Woodward's expressions are often too general. He appears to assert, that shells are found as frequently, and in as great abundance, in flints, cornelians, chalcedonii, ores, and sulphur, as in other matters. But the fact is, that shells are a very rare phænomenon in vitrifiable or purely inflammable substances: and, in chalk, marl, and marbles, the quantity of them is so prodigious, that it is impossible to affirm that the lighter and heavier shells are uniformly found in strata corresponding to their specific gravities, though, in general, this may be the case, oftener than otherwise. They are all impregnated with the bodies in which they are immersed, whether in the horizontal beds, or in the perpendicular fissures; because the whole has been affected by the operation of water, though at different times and in different manners. Those found in the horizontal beds of stone, marble, &c., have been transported and deposited by the waves of the sea; and those found in flints, cornelians, and other matters, peculiar to the perpendicular fissures, were formed by rills of water

impregnated with lapidific or metallic substances. In both cases, the matter that fills the shells has been in the state of a fine impalpable powder; because every pore of them is completely filled, and the moulds of them are as exact as the impressions of a seal upon wax.

It is, therefore, apparent, that in stone, marble, &c., there are multitudes of shells so entire, and so well preserved, that they may be compared with those in our cabinets, or upon the shores of the sea.

"There being, I say, besides these, such vast multitudes of shells contained in stone, &c., which are entire, fair, and absolutely free from any such mineral contagion; which are to be matched by others at this day found upon our shores, and which do not differ in any respect from them; being of the same size that those are of, and the same shape precisely; of the same substance and texture, as consisting of the same peculiar matter, and this constituted and disposed in the same manner as is that of their respective fellow kinds at sea; the tendency of the fibres and striæ the same; the composition of the lamellæ, constituted by these fibres, alike in both; the same vestigia of tendons (by means whereof the animal is fastened and joined to the shell); in each the same papillæ; the same sutures, and every thing else, whether within or without the shell, in its cavity, or upon its convexity, in the substance, or upon the surface of it. Besides, these fossil shells are attended with

they sometimes grow to one another, the lesser shells being fixed to the larger: they have the balani, tubuli vermiculares, pearls, and the like, still actually growing upon them. And, which is very considerable, they are most exactly of the same specific gravity with their fellow kinds now upon the shores. Nay farther, they answer all chemical trials in like manner as the sea shells do; their parts, when dissolved, have the same appearance to view, the same smell and taste*."

I have often observed with astonishment, whole mountains, chains of rocks, and extensive quarries, so full of shells, and other sea bodies, that there was hardly space left for the matters in which they are deposited.

I have seen some arable fields so full of petrified cockles, that they might be picked up by a blind man, others entirely covered with cornu ammonis, and others with cardites; and the more this subject is inquired into, we shall be the more thoroughly convinced, that the number of petrifactions is infinite, and that it was absolutely impossible that all the animals which inhabited these shells could exist at the same time.

I have farther remarked, that the stones of those arable lands which abound with petrified shells in an entire form, well preserved, and detached from all other matter, are frittered down

* Woodward, p. 23, 24.

by frost, which destroys stones, but has little effect upon petrified shells.

These immense quantities of petrified sea bodies, found in so many different places and situations, prove, that they could not be transported and deposited by the waters of the deluge; for the greatest part of them, instead of being found in the bowels of the earth, and in solid marble at the depth of seven or eight hundred feet, must have remained on the surface.

In all quarries, petrified shells form part of the internal structure of the stone, the surface of which is often covered with stalactites, a matter much less ancient than the stone that contains the shells. Another proof that these shells could not be derived from the deluge is, that the bones, horns, claws, &c., of land animals, are seldom found in a petrified state, and are never incorporated in marble, or other hard stones, whereas, if these effects had been produced by the deluge, the remains of land animals would have been found in marbles, as well as those of fishes*.

To allege, that the earth was entirely dissolved at the time of the deluge, is a mere gratuitous supposition, which required a second miracle in order to give water the power of an universal dissolvent. Besides, it infers an evident contradiction; for, if water was then an universal menstruum, how could shells have been pre-

* Ray's Discourses, p. 178, &c.

served in the entire state in which we find them? This is an evident demonstration, that no such dissolution took place, and that the parallel strata were not formed in an instant, but were gradually produced by successive sediments; for, it is apparent to every observer, that the disposition of all the materials composing the earth has been occasioned by the operation of water. The only question, therefore, that remains, is, whether this arrangement of parts was produced all at once, or in a succession of time? Now, it has already been shown, that it could not possibly happen at one time; because the materials are not disposed according to their specific gravities, and because they never suffered a general dissolution. This arrangement, therefore, must have originated from successive sediments. Any other cause, or particular revolution, would have given rise to an arrangement totally different. Besides, particular revolutions, or accidental causes, could never have produced a uniform disposition of horizontal and parallel strata throughout the whole globe.

Let us attend to what the historian of the Academy * has said upon this subject.

" The many marks of extensive inundations †, and the manner in which mountains must be conceived to have been produced ‡, demonstrate, that the surface of this earth has suffered great

* Ann. 1718, p. 3.

† Memoires, p. 287.

‡ l'Histoire de 1703, p. 22.; de 1706, p. 9.; de 1708, p. 34; et de 1716, p. 8, &c.

revolutions. However deep we penetrate into the globe, we discover nothing but ruins, bodies of different kinds amassed and incorporated without any order or apparent design. If there be any regularity in the structure of the earth, it lies too deep for our researches; we must, therefore, confine ourselves to the ruins of the external crust, which will be sufficient to occupy the attention of philosophers.

"M. de Jussieu discovered, in the neighbourhood of St. Chaumont, a great quantity of slaty or laminated stones, every lamina of which was marked with the impression of a stem, leaf, or other portion of some plant. The impressions of leaves were uniformly extended, as if they had been stretched in the stones by the hand; a clear demonstration, that they had been transported by water, which always keeps leaves in that position: their situations were various, and sometimes they lay across each other.

"It is natural to imagine, that a leaf deposited by water upon soft mud, and then covered by a similar layer of mud, would impress upon the undermost layer the figure of its one side, and upon the uppermost the figure of its opposite side; and, after these layers hardened and petrified, that they would each bear an impression of a different side of the leaf. But this supposition, however natural, does not take place: the two laminæ of stone uniformly bear the impression of the same side of the leaf, the one in alto, the other in bass relief. For this obser-

vation, with regard to the figured stones of St. Chaumont, we are indebted to M. de Jussieu; but we leave the explication of it to himself, and shall proceed to remarks of a more general and interesting nature.

"All the impressions on the stones of St. Chaumont are of foreign plants, which are not to be found in any part of France; they are natives either of the East Indies, or of the warmer climates of America. Most of them belong to the capillary tribes, and they are generally particular species of ferns, the close texture of which enables them both to make deep impressions, and to remain long in a state of preservation. M. Leibnitz was astonished to find the impressions of the leaves of a few East India plants upon some stones in Germany: in the example under consideration, the wonder is greatly augmented; for, by some unaccountable destination of nature, it would appear, that, in all the stones of St. Chaumont, not a single impression of a native plant is to be found.

"From the number of fossil shells in the mountains and quarries exhibited in this country, as well as in many others, it is apparent, that it must have formerly been covered with the sea. But how could the American or Indian Oceans come hither?

"To solve this and other surprising phænomena, we may suppose, with much probability, that the sea originally covered the whole globe. But this supposition will not answer; because no terrestrial plants could then exist:

the plants of one country, therefore, could only be transported to another by great inundations.

"M. de Jussieu imagines, that as the bed of the sea is always rising higher by means of the mud and sand incessantly carried into it by the rivers, the sea, at first confined by natural dikes, might at last surmount them, and spread over the land to great distances; or, which would produce the same effect, the dikes might in time be rendered so thin, by the constant operation of the water, that they would at last give way. Soon after the formation of the earth, when nothing had assumed a regular or settled form, sudden and prodigious revolutions might then be produced, of which we have now no examples, because every thing is in such a fixed and permanent state, that only slow and inconsiderable changes can take place: it is for this reason that we find a difficulty in crediting revolutions more sudden and tremendous.

"By some of these great revolutions the West or East Indian Oceans might have been poured in upon Europe: in their journey, they would tear up foreign plants, carry them off floating on the waves, and gently deposit them in shallow places, from which the waters would soon evaporate."

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE IX.

Of the Inequalities upon the Earth's Surface.

THOUGH the inequalities upon the surface of the earth may be considered as a deformity in its figure, they are absolutely necessary to vegetation and animal life. To be convinced of this fact, we need only consider what would be the condition of the earth, were its surface perfectly smooth and regular. Instead of those beautiful hills which furnish abundance of water for supporting the verdure of the earth, instead of those richly garnished fields, where plants and animals find an easy and comfortable subsistence, a dreary ocean would cover the whole globe, and the earth, deprived of all its valuable and alluring qualities, would be an obscure abandoned planet, suited only for the habitation of fishes.

But, independent of moral considerations, which seldom ought to be employed in natural

philosophy, the surface must, from a physical necessity, have been irregular; for, supposing it to have been originally smooth and level, the motion of the waters, subterraneous fires, the winds, and other external causes, would necessarily produce, in time, irregularities similar to those which we now behold.

Next to the elevation of mountains, the depths of the ocean form the greatest inequalities. This depth is exceedingly diversified, even at great distances from land. In some places the sea is said to be a league in depth; but that is a rare phænomenon; and the most common depths are from 60 to 150 fathoms. Gulfs and branches of the ocean which run in upon the land, are still less deep; and straits are generally the most shallow places.

Depths are commonly sounded by a piece of lead, of 30 or 40 pounds weight, fixed to a small rope. This method answers well enough for ordinary depths, but it is liable to error when the depth is very great; for the cord being specifically lighter than water, after much of it has been wound down, the weight of the lead and that of the cord become nearly equal to their bulks of water; then the lead descends no more, but runs off in an oblique line, and floats at the same depth. Hence, in sounding great depths, an iron chain, or some body heavier than water, should be employed. It is for want of attention to this circumstance, that some navigators have been led to maintain, that the sea, in many places, has no bottom.

In general, the depths in open seas augment or diminish in a pretty regular manner, being commonly deeper the farther from land. But to this remark there are many exceptions; for there are places in the middle of the sea, as at the *Abrolhos* in the Atlantic, where large shelves appear; and there are, in other places, vast sand-banks, well known to the mariners who sail to the East Indies.

Along coasts, the depths are likewise very irregular. However, it may be laid down as a certain rule, that the depth is always proportioned to the height of the coast: the same observation applies to rivers.

It is easy to measure the height of mountains, either geometrically, or by the barometer. This instrument determines the height of a mountain pretty exactly, especially in countries where its variation is not considerable, as at Peru and other equatorial climates. By one or other of these methods, the height of most mountains has already been ascertained; for example, it has been found, that the highest mountains of Switzerland exceed Canigau, the most elevated of the Pyrennees, 1,600 fathoms*. These mountains appear to be the highest in Europe, since they give rise to a great number of rivers which run into different and very distant seas, as the Po, which empties itself in the Adriatic, the Rhine, which loses itself in the sands of Holland, the Rhone, which falls into the Mediter-

* See Hist. de l'Acad. 1708, p. 24.

ranean, and the Danube, which runs into the Black Sea. These four rivers, the mouths of which are so distant, derive part of their waters from St. Gothard and the neighbouring mountains; a clear proof that this place is the most elevated part of Europe.

Mount Taurus, Imaus, Caucasus, and the mountains of Japan, are higher than any in Europe. The mountains of Africa, as the great Atlas, and the mountains of the Moon, are at least equally high with those of Asia; and the highest of all are those of South America, and especially of Peru, which are 3,000 fathoms above the level of the sea. In general, the tropical mountains are more elevated than those of the temperate zones, and those of the latter are higher than those nearer the poles. Thus, the nearer the equator, the greater are the superficial inequalities, which, though considerable with regard to us, are nothing when estimated in relation to the whole globe. A difference of 3,000 fathoms in 3,000 leagues diameter, is but a fathom to a league, or a foot to 2,200 feet, and, upon a globe of 2½ feet, would not make the 16th part of a French line. Hence this earth, which to us appears to be traversed and intersected by mountains of an enormous height, and by seas of a dreadful depth, is, in relation to its size, but slightly furrowed with inequalities so inconsiderable, that they cannot make any variation upon its general figure.

In continents, the mountains form continued chains; but, in islands, they are more inter-

rupted, generally rise in the form of a cone, or pyramid, and are distinguished by the name of peaks. The Peak of Teneriffe, is one of the highest mountains in the earth; it is nearly a league and a half perpendicular above the level of the sea. The Peak of St. George, in one of the Azores, and the Peak of Adam, in the island of Ceylon, are likewise exceedingly high. These peaks are composed of rocks, piled above each other; and all of them throw out, from their summits, fire, ashes, bitumen, minerals, and stones. Some islands, as St. Helena, Ascension Isle, and most of the Canaries and Azores, are only the tops or points of mountains. It is also worthy of remark, that the middle of most islands, promontories, and capes, is the most elevated, and that they are generally divided into two parts, by chains of mountains which run in the direction of their greatest length: in Scotland, for example, the Grampian mountains (Grans-bain) extend from east to west, and divide the island of Great Britian into two parts: the same thing takes place in Sumatra, the Lucca Islands, Borneo, Celebes, Cuba, St. Domingo, the peninsulas of Corea and Malaya, &c. Italy is also longitudinally traversed by the Appennines.

Mountains, as mentioned above, are of different heights; the hills are lowest; then follow the mountains of an ordinary height, which are succeeded by a third range still higher. All these are commonly covered with trees and plants; but neither of them furnish springs ex-

cept at their bottoms. In the last and highest range, we find nothing but sand, loose stones, flints, and rocks, the tops of which often reach above the clouds. Precisely at the foot of these rocks, are little plains or hollows, which collect rains and snow, and form those ponds, morasses, or fountains, from which the rivers derive their sources *.

The figure of mountains is likewise very different. Some consist of long chains of nearly an equal height; others are intersected by deep valleys; the contours of some mountains are pretty uniform; those of others are most irregular, and sometimes a detached little mountain appears in the middle of a plain or valley. There are also two kinds of plains; some occupy the low grounds, and others appear in the mountains. The former are generally divided by some large river; but the latter, though their extent be considerable, are dry, or furnished with a small rill only. The plains in the mountains are often exceedingly high, always of difficult access, and form one country above another, as in Auvergne, Savoy, and other elevated provinces. The soil of them is firm, and produces plenty of herbs and odoriferous plants, which make them the finest pasture-grounds in the world.

The tops of high mountains are composed of rocks of different elevations, which, when viewed at a distance, make them resemble the waves

* See Lettres Philosophiques sur la Formation des Sels, &c., p. 198.

of the sea*. This is not the only reason for our affirming that mountains were formed by the motions of the sea; I only mention it, because it corresponds with every other phænomenon. But the following facts put this point beyond all controversy: the fossil shells, and other sea bodies, every where found in such profusion that they could not possibly be transported from the sea, in its present state, into continents so distant, and deposited at such great depths in the bowels of the mountains: the universal parallelism of the different strata, an effect which could only be produced by water, and the composition even of the most dense of them, as those of stone and marble, which clearly evinces, that, before their formation, they had been reduced into a fine powder, and precipitated to the bottom in the form of sediments: the exactness with which the fosssil shells are moulded in the matters in which they are found: the cavities of fossil shells, which are uniformly filled with the same substances that contain them: the corresponding angles of hills and mountains, which nothing could effect but the currents of the ocean: the equality in the heights of opposite hills, and the different strata uniformly appearing at the same levels: and, lastly, the direction of mountains, the chains of which extend longitudinally, like the waves of the sea.

* See Lettres Philosophiques sur la Formation des Sels, &c., p. 196.

With regard to the depths or hollows on the surface of the earth, those of the ocean are unquestionably the greatest. But, as these are hid from human view, and can only be discovered by sounding, we shall confine ourselves to those which appear on the dry land, such as deep valleys, precipices found between rocks, abysses that present themselves in high mountains, as the abyss of Mount Ararat, the precipices of the Alps, the valleys of the Pyrennees, &c. These depths are a natural consequence of the elevation of mountains; they receive the water and earth carried down from the high grounds; their soil is generally fertile; and they are full of inhabitants. The precipices among rocks are often occasioned by a sudden sinking of one side, the base, which generally inclines more one way than another, being loosened by the action of the air, and of frost, or by the violence of torrents. But abysses, or those enormous precipices that appear on the tops of some mountains, and, to the bottom of which, though their circumference be a mile and a half, or three miles round, it is impossible to descend, have been formed by the operation of fire. They have been the furnaces of ancient volcanoes, the matter of which has been exhausted by explosions, and the long action of fires that are now extinguished by the defect of combustible matter. Of this kind is the abyss of Mount Ararat, described by Tournefort. It is surrounded with rocks which are black and burnt. The abysses of Ætna and of Vesuvius will have the

same appearance after their inflammable materials are exhausted.

In Plot's history of the county of Stafford, in England, there is an account of a kind of gulf, which was sounded by a rope of 2,600 feet, without finding either water or bottom, the rope being too short *.

The greatest cavities, and the deepest mines, are generally in the mountains, and seldom descend to the level of the plains. By them we discover the internal structure of the mountain only, not that of the globe itself.

Besides, these depths are not very considerable. Mr. Ray affirms, that the deepest mines exceed not half a mile. The mine of Cotteberg, which, in the time of Agricola, was esteemed to be the deepest in the world, was only 2,500 feet in perpendicular depth. There are, indeed, holes in particular places, as that mentioned by Plot, or Pool's Hole in the county of Derby, the depth of which is probably very great; but none of them bear any sensible proportion to the thickness of the globe.

If the kings of Egypt, in place of erecting pyramids as monuments of their vanity and riches, had expended equal sums in making profound excavations into the bowels of the earth, to the depth of perhaps a league, they might have discovered substances which would have recompensed their labour; they would at least have extended the knowledge of the earth's in-

* See Journal des Savans, 1680, p. 12.

ternal structure, which might have been productive of much utility.

But, let us return to the mountains. The highest of them lie between the tropics; and the nearer we approach to the equator, the greater are the inequalities on the earth's surface. A short enumeration of mountains and islands will be sufficient to establish this point.

In America, the Cordeliers, which are the highest mountains in the world, lie precisely under the equator, and they extend on both sides a considerable way beyond the tropic circles.

Our mathematicians who were sent to Peru, as well as some other travellers, have measured the height of these mountains above the level of the South Sea. Some of them were measured geometrically, and others by the barometer, which, being subject to little variation in that climate, gives the heights nearly as exact as a geometrical measurement. The following are the results of their observations.

Heights of the most elevated Mountains of the Province of Quito in Peru.

	Fathoms.
Cota-catché, to the north of Quito .	2,570
Cayambé-orcou, under the equator .	3,030
Pitchincha, a volcano in 1539, 1577, and 1660	2,430
Antisana, a volcano in 1590	3,020
Sinchoulogoa, a volcano in 1660 . .	2,570
Illinica, supposed to be a volcano . .	2,717

	Fathoms.
Coto-paxi, a volcano in 1533, 1742, and 1744	2,950
Chinboraço, a volcano; the date of its eruption unknown	3,220
Cargavi-raso, a volcano in 1698	2,450
Tongouragoa, a volcano in 1641	2,620
El-altan, one of the mountains called Coillanes	2,730
Sanguaï, a volcano which has burnt since the year 1728	2,680

By comparing the heights of the mountains of South America with those of our Continent, we perceive that, in general, they are one fourth part higher than the mountains of Europe, and that almost the whole of them have been and actually are volcanoes. But even the highest mountains in the interior parts of Europe, Asia, and Africa, have been extinguished long beyond the record of history. It is true, that, in several of these last mountains, we evidently recognise the ancient existence of volcanoes, as well by the black and burnt sides of precipices, as by the nature of the matters which surround them, and which extend along the ridges of the mountains. But, as these mountains are situated in the interior parts of continents, and now very distant from the sea, the action of the subterraneous fires, which cannot produce great effects but by the shock of water, ceased after the seas retired. It is for this reason, that, in the Cordeliers, whose roots may be said to border upon the South Sea, most of the peaks are actual

volcanoes; while the volcanoes of Auvergne, Vivarais, Languedoc, Germany, Switzerland, &c., in Europe; and those of Mount Ararat in Asia; and of Mount Atlas in Africa, have long been absolutely extinct.

The height at which vapours freeze is about 2,400 fathoms in the torrid zone, and about 1,500 in France. The tops of high mountains sometimes surpass this line from 800 to 900 fathoms, and all this space is covered with snow which never melts. The highest clouds rise not above 300 or 400 fathoms above these mountains, and consequently exceed the level of the sea about 3,600 fathoms. Hence, if the mountains were still higher, we should see, in the torrid zone, a belt of snow commencing at 2,400 fathoms above the level of the sea, and terminating at 3,500 or 3,600 fathoms, not on account of the cessation of the cold, which augments in proportion to the elevation, but because the vapours would not rise higher *.

M. de Keralio, a learned philosopher, has collected the heights of the mountains in several countries, from the measurements of different persons.

In Greece, M. Bernoulli determined the height of Mount Olympus to be 1,017 fathoms. Hence the snow cannot lie upon it perpetually; neither can snow lie constantly on Pelion in Thessaly, nor on Cathalylium and Cyllene; because the height of these mountains does not rise to the

* Mem. de l'Acad. des Sciences, ann. 1744.

freezing degree. M. Bougner assigns 2,500 fathoms as the height of the Peak of Teneriffe, the top of which is always covered with snow. Mount Ætna, the Norwegian Mountains, the Hemus, the Athos, the Atlas, the Caucasus, and several others, such as Mounts Ararat, Taurus, and Libanus, are perpetually covered with snow, near their summits.

	Fathoms.
Pontoppidan informs us, that the highest mountains of Norway are	3,000
Note, This measure, as well as the following, appears to be exaggerated.	
According to M. Brovallius, the highest mountains of Sweden are	2,333
The following, according to the Memoirs of the Academy of Sciences, are the highest mountains of France.	
Le Cantal	984
Mount Ventoux	1,036
Le Canigou of the Pyrennees	1,441
Le Moussec	1,253
Le Saint Barthélemy	1,184
The Mountain of Gold in Auvergne, an extinguished volcano	1,048
According to Mr. Needham, the height of the mountains of Savoy are,	
The Convent of St. Bernard	1,241
The Rock to the south of St. Bernard .	1,274
Mount Serène	1,282
L'Allée Blanche	1,249
Mount Tournè	1,683

	Fathoms.
According to M. Facio de Duiller, Mount Blanc, or the Cursed Mountain, is .	2,213

It is certain, that the chief mountains of Switzerland are higher than those of France, Spain, Italy, and Germany. Several learned men have ascertained the height of these mountains.

The greatest part of these mountains, according to M. Mikhéli, as the Wetter-horn, the Schreck-horn, the Eighess-Schneeberg, the Fisher-horn, the Stroubel, the Fourke, the Loukmarier, the Crispalt, the Mougle, the ridge of Baduts and Gottard, are from 2,400 to 2,750 fathoms above the level of the sea. But these measures, I suspect, are too high, especially as they exceed, by one half, those given by Cassini, Scheuthzer, and Mariotte, which may be estimated too low, but not to this extent. My suspicion is farther confirmed, by considering that, both in the cold and temperate regions, where the air is always troubled with storms, the barometer is subject to so great variations, that its results cannot be trusted.

With regard to the direction of these mountains, the Alps form a continued chain which runs across the whole Continent from Spain to China. They commence on the sea-coast of Galicia, join the Pyrennees, traverse France, by Vivares and Auvergne, run through Italy, and stretch into Germany, above Dalmatia, until they reach Macedonia; from thence they join the mountains of Armenia, the Caucasus, the

Taurus, the Imaus, and at last terminate on the coast of Tartary. Mount Atlas, in the same manner, traverses the whole Continent of Africa, from the kingdom of Fez to the straits of the Red Sea. The mountains of the Moon have likewise the same direction.

But the mountains of America have an opposite direction. The vast chains of Cordeliers, and other mountains, run more from south to north than from east to west.

This last assertion requires to be modified; for though, at first sight, we may follow the mountains as far as China, by passing from the Pyrennees in Auvergne, to the Alps in Germany, and in Macedonia, to Caucasus and other mountains of Asia, as far as the Tartarian Sea; and though Mount Atlas, in the same manner, appears to traverse the Continent of Africa from west to east, the middle of this vast peninsula may still consist of a chain of high mountains stretching from Mount Atlas to the mountains of the Moon, and from these to the Cape of Good Hope: in this view, the middle of the Continent of Africa may be considered as consisting of mountains which run from north to south through its whole extent, like the mountains of America. Those parts of Mount Atlas which traverse Africa from west to east, should be considered as branches only of the principal chain. The mountains of the Moon, which run from west to east, may likewise be regarded as collateral branches; and, if there are no volcanoes in this prodigious range of mountains, it may be owing to the vast dis-

tance of the sea from the middle regions of Africa; whilst, in America, the sea is very near the foot of the high mountains, which, instead of occupying the middle of the peninsula of South America, are all situated to the west; and the extensive low lands are entirely on the east side.

The great chain of the Cordeliers are not the only mountains of America which run from north to south. In the territory of Guiana, about one hundred and fifty leagues from Cayenne, there is a chain of pretty high mountains, which also extends from north to south. On the Cayenne side, this chain is so steep, that these mountains are almost inaccessible. This steepness seems to indicate, that, on the other side, the declivity is gentle, and consists of fine land. The tradition of the country, accordingly, or rather the testimony of the Spaniards, is, that, beyond the mountains, there are populous nations of savages united into regular societies. It is likewise said, that there is a gold mine in these mountains, and a lake in which grains of gold are found: but this fact requires confirmation.

In Europe, the chain of mountains which begins in Spain, and passes through France, Germany, and Hungary, divides into two great branches, one of which extends into Asia by the mountains of Macedonia, Caucasus, &c., and the other branch stretches from Hungary into Poland and Russia, and extends as far as the sources of the Wolga and Boristhenes; and, stretching still farther, it joins another chain in Siberia, and terminates in the North Sea to the

west of the river Oby. These chains of mountains ought to be regarded as one continued ridge, from which several large rivers derive their sources: some of these rivers, as the Tagus, and the Doura in Spain, the Garonne and the Loire in France, and the Rhine in Germany, empty themselves into the ocean; others, as the Oder, the Vistula, and the Niemen, fall into the Baltic Sea; others, as the Dwina, fall into the White Sea, and the river Petzora empties itself into the Frozen Sea. On the east side, this chain of mountains gives rise to the Yeucar and Ebre in Spain, to the Rhone in France, and to the Po in Italy, which falls into the Mediterranean; to the Danube and Don, which lose themselves in the Black Sea; and, lastly, to the Wolga, which falls into the Caspian.

Norway is full of rocks and groups of mountains. There are plains, however, which extend, without interruption, six, eight, and ten miles. Their direction is not from west to east, like that of the other European mountains. On the contrary, they stretch, like the Cordeliers, from south to north *.

In the south of Asia, from the island of Ceylon to Cape Comorin, there is a chain of mountains which separates Malabar from Coromandel, traverses the Mogul country, joins Mount Caucasus, stretches through the country of the Calmucks, and terminates in the North Sea to

* Hist. Nat. de Norwege, par Pontoppidan. Journal Etranger, mois d'Aout, 1755.

the east of the Irtis. Another chain extends from north to south as far as Razatgat in Arabia, and may be traced, at some distance from the Dead Sea, as far as Jerusalem: it surrounds the extremity of the Mediterranean, and the point of the Black Sea, from which it traverses Russia, and terminates in the North Sea.

We may likewise remark, that the mountains of Indostan and those of Siam run from south to north, and both unite with the rocks of Thibet and Tartary. Each side of these mountains presents a different season: on the west, they have six months of rain, while, on the east, they enjoy the finest weather *.

All the mountains of Switzerland, as those of the Vallais and the Grisons, those of Savoy, Piedmont, and Tirol, form a chain, which extends, from north to south, as far as the Mediterranean. Mount Pelate, which is situated in the centre of Lucerne, nearly in the centre of Switzerland, forms a chain of about fourteen leagues, extending from north to south as far as the canton of Bern.

We may therefore conclude, in general, that the greatest eminences of this globe are situated from north to south, and that those which run in other directions ought to be regarded as collateral branches only of these primitive mountains: and, it is partly by this disposition of the primitive mountains, that all the points or terminations of continents are either south or

* Hist. Phil. et Polit. tom. ii. p. 46.

north; as appears from the points of Africa, of America, of California, of Greenland, of Cape Comorin, of Sumatra, of New Holland, &c. This fact seems to prove, as formerly remarked, that the waters have proceeded in greater quantities from the south than from the north pole.

If we consult a new map of the world, in which are represented, round the Arctic Pole, all the lands of the four quarters of the globe, except the north point of America, and round the Antarctic Pole, all the seas, and the small portions of land to be found in the southern hemisphere, we shall evidently perceive, that many more revolutions have happened in the latter than in the former hemisphere, and that the quantity of water has always been, and still is, much greater there than in our hemisphere. Every thing concurs in proving, that the greatest inequalities of the globe exist in the southern regions, and that the general direction of the primitive mountains is from north to south, rather than from east to west, through the whole extent of the earth's surface.

What we have now remarked concerning the greatest elevations of the land, applies equally to the greatest depths of the sea. The most extensive and deepest seas lie nearer the equator than the poles. From these united observations, the truth of our general position, that the greatest inequalities of the globe are to be found in the equatorial regions, is sufficiently established. These irregularities on the surface of the earth give rise to a number of curious phænomena. Between the Indus and the Ganges, for example,

there is a large peninsula, through the middle of which runs a chain of high mountains, called the *Gauts*, which extends from north to south, from the extremity of Mount Caucasus to Cape Comorin. One side of this peninsula forms the coast of Malabar, the other that of Coromandel. On the Malabar side, between the chain of mountains and the sea, the season of summer is from September to April; and, during these months, the sky is serene, and no rain falls. But on the Coromandel coast, which lies on the other side of the mountains, this very period is their winter, and the rains fall in torrents. This reverse of summer and winter happens, in some places, no farther distant than twenty leagues; so that, by crossing the mountains, a man has it in his power to change seasons. The same thing, it is said, takes place at Cape Razalgate in Arabia, and even in Jamaica, which is divided from east to west by a chain of mountains. On the south side of these mountains, the plantations enjoy the warmth of summer, while those on the north suffer all the rigours of winter. Peru, which is situated under the line, and extends about 1,000 leagues toward the south, is divided into three long and narrow portions, called by the inhabitants *Lanos*, *Sierras*, and *Andes*. The Lanos, which are the plains, extend along the coast of the South Sea; the Sierras are hills interspersed with valleys; and the Andes are the famous Cordeliers, the highest mountains of the world. The Lanos are about ten leagues broad; the Sierras, in many places,

twenty leagues; and the Andes nearly the same, though some parts of them are more, and others less broad. The breadth of these divisions is from east to west, and their length from south to north. This part of the world exhibits the following remarkable appearances: 1st, Along the whole coast of the Lanos, a south-west wind almost constantly blows, which is contrary to the ordinary direction of the wind in the torrid zone. 2d, In the Lanos, it never rains or thunders, though there are plenty of dews. 3d, It rains almost continually at the Andes. 4th, In the Sierras, which lie between the Lanos and the Andes, it rains from September to April.

It was long thought that all high mountains run from west to east, till the contrary direction was discovered in America. But M. Bourguet was the first who remarked the surprising regularity in the structure of these great masses. After passing the Alps thirty times in fourteen different places, the Appennines twice, and making several tours in the neighbourhood of these mountains; and of Mount Jura, he found, that the contours of all mountains have a near resemblance to the works in regular fortifications. When the direction of a mountain is from west to east, all its projections, or advances, stretch to the south and north. This amazing regularity is so remarkable in the valleys, that a man is apt to imagine he is walking in a covered way. If, for example, a man travels in a valley from north to south, he perceives that the mountain which lies to the right hand makes

projections to the east, and that the projections of the opposite mountains regard the west, in such a manner, that the prominent and concave angles, on each side, alternately correspond with one another. When the valleys are large, the angles of the mountains are less acute, because they are more distant from each other, and the declivity is not so rapid or steep. These angles are not perceptible in plains, except when we station ourselves on the banks of the rivers, which generally occupy the middle of the plains, and whose natural windings correspond to the most advanced angles or projections of the mountains. It is astonishing that such an obvious fact should have remained so long unnoticed; for, it is apparent, that, in valleys lined with opposite mountains, when the declivity of one of the mountains is less rapid than that of the other, the course of the rivers is not in the middle, but nearer to the steepest mountain *.

These general observations might be confirmed by a multitude of facts. The mountains of Switzerland, for example, are steeper on the south side than on the north, and on the west side than on the east. This appearance is obvious in Mount Gemmi, Mount Brisa, and in almost all the other mountains in this country, the highest of which are those which separate Vallesia, and the Grisons of Savoy, from Piedmont and Tirol. These countries are, indeed,

* See Lettres Philosophiques sur la Formation de Sels, p. 181, 200.

a continuation only of the same mountains, the chain of which extends to the Mediterranean; and the Pyrennees are a continuation only of that vast mountain, which commences in Upper Vallesia, whose branches stretch far to the west and south, and preserve, throughout that whole extent, a great height; but, on the north and east sides, they gradually sink into plains, as appears in those extensive countries which are traversed by the Rhine and Danube before they finish their course, while the Rhone descends with rapidity to the south, and empties itself into the Mediterranean. The same observation is exemplified in the mountains of England and of Norway. But the most perfect example is afforded by the mountains of Chili and Peru. The Cordeliers are exceedingly steep on the west side; but they have a gradual declivity to the east, and terminate in vast plains, which are watered by the greatest rivers in the world *.

M. Bourguet, to whom we are indebted for the discovery of the correspondence between the angles of mountains, calls this discovery *the Key to the Theory of the Earth.* However, he appears not to have perceived its whole importance; for, in his treatise on this subject, he gives the skeleton only of an hypothetical system, in which most of his conclusions are either false or uncertain. The theory that we have delivered rests upon four principal facts, the truth of which, after examining the proofs that support

* See Phil. Trans. Abridg. vol. vi. part vi. p. 158.

them, cannot admit of a doubt: the *first* is, That the earth, to very considerable depths, is every where composed of parallel strata of different matters, which were formerly in a fluid or soft state: the *second*, That the sea has, for many ages, covered the whole earth which we now inhabit: the *third*, That the tides and other motions of the waters, produce inequalities in the bottom of the sea: and the *fourth*, That the figure, and corresponding direction of mountains, have originated from currents in the ocean.

All the valleys and dales on the surface of the globe, as well as all the mountains and hills, have originated from two causes, namely, fire and water. When the earth first assumed its consistence, a number of inequalities took place on its surface; swellings and blisters arose, as happens in a block of glass or of melted metal. Hence this first cause produced the original and the highest mountains, which rest on the interior rock of the earth as their base, and below which, as every where else, there must have been vast caverns, which sunk in at different periods. But, without considering this second event, the falling in of the caverns, it is certain, that, when the earth first consolidated, it was every where furrowed with depths and eminences, which were produced solely by the action of cooling. Afterwards, when the waters were precipitated from the atmosphere, which happened when the earth cooled so much as to be unable to repel the vapours, these wa-

ters covered the whole surface of the globe to the height of two thousand fathoms; and, during their long abode upon our continents, the motion of the tides and that of the currents changed the disposition of the primitive mountains and valleys. These movements would form hills in the valleys, and would cover the bottoms and knaps of the mountains with new beds of earth; and the currents would produce furrows or valleys with corresponding angles. It is to these two causes, of which the one is much more ancient than the other, that the present external form of the surface of the earth is to be referred. Afterwards, when the seas sunk down, they produced those steep precipices on the west, where they ran with the greatest rapidity, and left gentle declivities on the east.

The structure of those eminences which were formed by the sediments of the ocean, is very different from that of those which owe their origin to the primitive fire. The first are disposed in horizontal beds, and contain an infinite number of marine productions. The second, on the contrary, are less regular in their structure, and include no marks of sea bodies. These mountains of the first and second formation have nothing in common but the perpendicular fissures; but these fissures are effected by two different causes. The vitrescent matters, in cooling, diminished in size, and, of course, they split, and receded to different distances. But those composed of calcarious matters transported by the waters, split into fissures solely by drying.

I have often remarked, that, in detached hills, the first effect of the rains is gradually to carry down from the summit the earth and other bodies, which form at the foot a pretty thick stratum of good soil, while the top is left entirely bare. This effect is, and necessarily must be, produced by the rains. But a previous cause disposed these and similar matters round all hills, not excepting those which are detached; for, on one side, the earth is uniformly better than on the other: the hills are always steep and precipitant on one side, and have a gentle declivity on the other; which proves clearly, that the action, as well as the direotion of the motion of the waters, were greater on one side than on the other.

After perusing the proofs contained in the subsequent articles, the reader will be enabled to determine whether I am right in maintaining, that these facts, when firmly established, will likewise ascertain the general theory of the earth. What has been remarked concerning the formation of mountains needs no farther explication. But, as it may be objected, that I have not accounted for the formation of peaks, or pointed mountains, nor for some other particular facts, I shall add such observations as have occurred upon this subject.

I have endeavoured to form a distinct and general idea of the manner in which the materials composing this earth are arranged, and have reduced the whole to two classes. The *first* includes all the matters which are disposed

in horizontal or regularly inclined beds or strata; and the *second* comprehends all those matters which appear in detached masses, in ridges, or in veins, either perpendicular or irregularly inclined. In the *first* class I rank sands, clays, granites, flints, and free-stones in large masses, pit-coal, slates, and likewise marls, chalk, calcinable stones, marbles, &c. In the *second*, I include metals, minerals, crystals, precious stones, and flints in small masses. Under these two classes, all the known materials of the earth are comprehended. Those of the first class owe their origin to sediments transported and deposited by the waters of the sea, and ought to be distinguished into such as are calcinable by the application of fire, and such as melt, and are convertible into glass. The matters comprehended under the second class are all vitrifiable, with the exception of those called inflammable, or which totally consume in the fire.

There are, in the first class, two distinct species of sand; the one, which abounds more than any other matter in the globe, is vitrifiable, or rather consists of fragments of real glass: The other, which is less in quantity, is calcinable, and ought to be regarded as the dust of stone, and as differing from gravel only by the grossness of its grains. In general, vitrifiable sand lies in beds; but they are frequently interrupted by masses of free-stone, of granite, and of flint; and sometimes these substances appear in banks of a considerable extent.

Sea shells are seldom found in this sand, or in vitrifiable bodies; and even those which appear in them are not disposed in beds, but scattered, as it were, by chance; I never, for example, found any in free-stone. This stone, which abounds in certain places, is nothing but sand united by a cement. It never appears but in countries where vitrifiable sand is frequent; and the quarries of it are generally in pointed hills, sandy lands, or interrupted eminences. These quarries may be wrought on all sides; and, when they appear in large beds, they are more distant from each other than those of marble or calcinable stones. Blocks of free-stone may be cut of all dimensions; and, though it be difficult to work, its hardness is inconsiderable; for it is easily reduced to sand by friction, except the black points or nails sometimes found in it, which are so hard as to resist the best files. Common rock-stone, which I consider as a species of granite, is vitrifiable, and of a similar nature with free-stone; it is only harder, and more firmly cemented. It has likewise several dense points, which cut the shoes of travellers on mountainous grounds. It also contains a great number of talky spangles; and the whole is so hard as not to be worked without great labour.

After narrowly examining these hard points found in free-stone and granite, I discovered that they consist of metallic matter, which has been melted and calcined by a strong fire, and that they have a perfect resemblance to certain sub-

stances thrown out of volcanoes, of which I have seen vast quantities in Italy. They are called by the inhabitants *Schiarri*. They are black, heavy masses, upon which neither fire, water, nor the file, can make any impression. This metallic matter is different from lava, the latter being a species of glass; but the former seems to partake more of metal than of glass. The points in free-stone and granite have a great resemblance to this matter, which is a farther proof that those substances have formerly been liquified by fire.

This seems to indicate that the great masses of free-stone have originated from the action of the primitive fire. I at first imagined that this matter owed its density and the adhesion of its particles solely to the intervention of water. But I have since learned that the action of fire produces the same effect; and I shall relate some experiments which at first surprised me, but which I have repeated so often as to remove every doubt upon this subject.

EXPERIMENTS.

I pounded free-stones of different degrees of hardness, till they were reduced to a powder more or less fine. This powder I employed to cover the cement I used in converting iron into steel. This powder of free-stone was strewed over the cement, and heaped up, in the form of a dome of three or four inches in thickness, on an earthern vessel of three feet long by two broad. After undergoing the action of the

fire in my blast furnaces, during several days and nights without interruption, it was no longer the powder of free-stone, but a mass so solid that we were obliged to break it in order to uncover the vessel which contained the iron, now converted into steel. The action of fire upon this powder of free-stone produced masses equally solid as free-stone of a middling quality, which does not ring under the hammer. This fact showed that fire, as well as water, could prove a cement to vitrifiable sand, and, consequently, might have formed those immense masses of free-stone which compose the nucleus of some of our mountains.

I am, therefore, fully persuaded, that all the vitrescent matters, of which the interior rock of the globe, as well as the nuclei of great mountains are composed, have been produced by the action of the primitive fire; and that the waters have only formed those accessory strata which surround these nuclei, which are all parallel and horizontal, or equally inclined, and in which we find the relics of shells and other productions of the ocean.

In the formation of free-stone and other vitrescent matters, I pretend not to exclude the intervention of water. On the contrary, I am inclined to believe, that vitrifiable sand may acquire consistence, and unite into masses more or less hard, perhaps more easily by means of water than by the action of fire. I have related the above facts solely with the view of preventing objections which would not fail to be made,

if it had been thought that I attributed the solidity of free-stones, and other bodies composed of vitrifiable sand, to the intervention of water alone. It is certain, that all the free-stone found on the surface, or at inconsiderable depths, has been formed by water; for, on the surface of these masses of free-stone, we perceive marks of undulations and rollings, and sometimes the impressions of plants and shells. But the free-stones formed by the sediments of water are easily distinguished from those which have been produced by fire. The latter have a coarser grain, and crumble down more easily than free-stone cemented by the intervention of water, which is more compact, and harder than that whose particles have been united by the action of fire.

Ferruginous matters assume a great degree of hardness by fire; for nothing is harder than cast iron. But ferruginous bodies may likewise acquire considerable density by the intervention of water. Of this fact I was ascertained by putting a quantity of filings of iron into vessels exposed to the rain. These filings formed a mass so hard, that it could only be broken by the hammer.

The vitreous rock which composes the interior mass of the globe, is harder than common glass. But it is not harder than certain volcanic lavas, and much softer than cast iron, which, however, is only glass mixed with ferruginous particles. This great hardness of the interior rock shows that it consists of the most fixed par-

ticles of matter, and that, from the time of their consolidation, they assumed the consistence and hardness which they still possess. Hence it cannot be objected to my hypothesis of general vitrification, that bodies reduced to glass by our furnaces are less hard than the rock of the globe; since cast iron, some lavas, or basalts, and even certain porcelains, are harder than this rock, and yet they derive their hardness from the action of fire alone. Besides, the elements of iron and other minerals, which give hardness to matters liquified by fire, or attenuated by water, existed, as well as the fixed earth, from the time that the globe was first consolidated: and I have already remarked, that the interior rock ought not to be regarded as pure glass, similar to that we make with sand and salts, but as a vitreous product mixed with matters the most fixed, and most capable of supporting the great and long continued action of the primitive fire, the great effects of which can only be compared in a very distant manner with the inconsiderable operations of our furnaces; and yet, from this comparison, though unfavourable, we clearly perceive what effects are common to the primitive fire and to our furnaces; and it shows, at the same time, that the degree of hardness depends less on the degree of heat than on the combination of matters submitted to its action.

On the tops of some high mountains, blocks of granite appear in great quantities. The positions of these blocks are so irregular, that they

seem to have been thrown together by accident; and we should be apt to imagine that they had tumbled down from some neighbouring height, if the places where they are found were not higher than any neighbouring ground. But their vitrifiable nature, and their angular and square figures, like those of free-stone rocks, discover these substances to have an uncommon origin. Thus, in large strata of vitrifiable sand, we find blocks of free-stone and granite, the figure and situation of which follow not exactly the horizontal position of strata. The rains have gradually brought down from the hills and mountains the sand with which these blocks were originally covered, by furrowing and cutting into those intervals that appear between the nuclei in free-stone, in the same manner as the hills of Fontainbleau are intersected. Every point of a hill resembles a nucleus in free-stone quarries, and all the intervals have been scooped out by the rains, and the sand they originally contained has been carried down to the valleys. In the same manner, the angular blocks of granite on the tops of high mountains were formerly covered and surrounded with vitrifiable sand, which, being gradually carried off by the rains, left the blocks in the position in which they happened to be formed. These blocks are generally pointed at the top, and augment in thickness towards their bases; one block often rests upon another, that upon a third, and so on, leaving irregular intervals between them: and as, in the course of time, the sand which covered

the blocks, and filled the intervals, was washed down by the rains, there would remain nothing on the tops of high mountains but pointed piles of irregular blocks; and hence the origin of peaks, or mountains ending in sharp points.

For, let it be supposed, as may easily be proved by the marine bodies found in the Alps, that this chain of mountains was formerly covered by the ocean, and that a thick bed of vitrifiable sand was deposited upon their tops, which reduced the whole chain to a level country. This bed of sand would necessarily give rise to large blocks of granite, of free-stone, of flint, and of other bodies, the consistence and figure of which originate from sand, nearly in the same manner as salts crystallize. These blocks, after the sand which covered them, and filled their interstices, was carried down to the plains, by rains, torrents, &c., would maintain their original stations, remain bare on the tops of the mountains, and constitute all those peaks or pointed eminences so frequently exhibited by Nature. To the same origin must be ascribed those high detached rocks which are found in China and other countries, as in Ireland, where they are distinguished by the name of *Devil's stones*, and the formation of which, as well as of peaked mountains, has hitherto appeared so difficult to explain. The explication, however, which I have given, is so natural, that it generally occurs to every person, who examines these objects; and, on this occasion, I will set down a passage from father Tertre. "From Yanchuin-yen we arrived at Hot-

cheou. Upon the road we remarked a singular phænomenon, namely, rocks of a surprising height, resembling square towers, in the midst of vast plains. I cannot account for this appearance, unless I be allowed to suppose these rocks to have formerly constituted a part of mountains, and that the earth, sand, and other loose parts, had been gradually washed away by the rains, and left rocks bare on all sides. What fortifies this conjecture is, that we saw some of them, the bases of which were still surrounded with earth to a considerable height *."

The tops of the highest mountains, often for 200 or 300 fathoms, consist of rocks of granite, free-stone, and other hard and vitrifiable substances: below these, we frequently meet with quarries of marble, or hard calcinable stone, full of fossil shells; as may be seen at the great Chartreuse in Dauphiny, and upon Mount Cenis, where the stones and marbles which contain shells are situated some hundreds of fathoms below the points or peaks of high mountains, though these beds of stone and marble be more than 1,000 fathoms above the level of the sea. Thus those mountains which have peaks or points generally consist of vitrifiable rocks; and those the summits of which are flat, contain, for the most part, marbles, and hard stones full of sea bodies. The same remark holds with regard to hills: for those composed of granite or free-stone are generally in-

* See Lettres Edifiantes, tom. i. p. 135.

tersected with points, eminences, cavities, and small valleys. But those composed of calcinable stone are nearly of an equal height, and are only interrupted by larger and more regular valleys, with corresponding angles; and they are crowned with rocks, uniform and level in their position.

Though these two species of mountains seem to be very different, their figures have been produced by the same cause, as has already been shown: but, it may be remarked, that the calcinable stones have suffered no change since the original formation of the horizontal strata. The vitrifiable sands, however, may have been changed and interrupted by the subsequent production of rocks and angular blocks which takes place in sand-beds. Both species have fissures. Those in calcinable rocks are almost always perpendicular; but those of granite and free-stone are somewhat more irregular in their direction. It is in these fissures that metals, minerals, crystals, sulphur, and all the substances of our second class, are found. Below the fissures the waters assemble, penetrate the earth, and give rise to the veins of water which every where appear under the surface.

I have endeavoured to explain, how the peaks of mountains have been deprived of the vitrifiable sands, which originally invested them; and my explanation errs in this circumstance only, that I attributed the first formation of the rocks, which form the nuclei of these peaks, to the intervention of water, instead of ascribing it to the action of

fire. These peaks or horns of mountains are nothing but prolongations of the interior rock of the globe, which were environed with great quantities of scoriæ and dust of glass. These loose materials must have been carried down by the movement of the sea, when it made its retreat. Afterwards, the rains and torrents of water would soon deprive the masses of pure rock of all their coverings, and make them completely bare, as they are at present. I may remark, in general, that no other change falls to be made in my theory of the earth than the following fact, that the first mountains derived their origin from the primitive fire, and not from the intervention of water, as I had conjectured; because I had then been induced to believe, by the authority of Woodward and some other naturalists, that shells were found on the tops of all mountains. But, from more recent observations, it appears that there are no shells on the highest summits, nor above two thousand fathoms above the level of the sea. Hence the waters have never surmounted those high summits, or at least have remained but a short time upon them; so that they have formed only the hills and the calcarious mountains, which never rise to the height of two thousand fathoms.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE X.

Of Rivers.

I HAVE already remarked, that, in general, the greatest mountains occupy the middle of continents; that those of a smaller kind divide islands, peninsulas, and promontories; that, in the Old Continent, the direction of the greatest chains of mountains is from west to east; and that those which run to the north or south are only branches of the principal chains. It will appear, on examination, that the greatest rivers have the same direction, and few of them follow the course of the branches of mountains. To be convinced of this fact, we have only to run our eye over a common globe; and, beginning with Spain, we shall find that the Vigo, the Douro, the Tagus, and the Guadiana, run from east to west, and the Ebro from west to east;

and that there is not a river of any consideration which runs from south to north, or from north to south, although Spain be almost entirely environed by the sea on the northern and southern parts. This remark concerning the rivers of Spain demonstrates, that the direction of the mountains is from west to east; that the southern provinces near the Straits are more elevated than the coast of Portugal; that, in the northern parts, the mountains of Galicia, the Asturias, &c., are a continuation only of the Pyrennees; and that this elevation of the country, both in the south and north, is the cause which prevents the rivers from running to the sea in these directions.

In examining the map of France, it is apparent that the Rhone is the only river which runs from north to south; and, even near one half of its course, from the mountains to Lyons, is from east to west: but the direction of all the great rivers, as the Loire, the Charente, the Garonne, and even the Seine, is from east to west.

The same observation holds with regard to Germany. The Rhine, like the Rhone, has the greatest part of its course from south to north: but the other large rivers, as the Danube, the Drave, and all the rivers which fall into them, run from west to east, and empty themselves in the Black Sea.

The Black Sea, which should rather be regarded as a large lake, is, from east to west, nearly three times as long as from south to north; and, consequently, its direction is similar

to that of the rivers. The same remark is applicable to the Mediterranean, which is nearly six times longer from east to west than from north to south.

The Caspian, it must be acknowledged, according to the chart made by order of the Czar Peter I., extends more from north to south, than from east to west. But the ancient charts represented it as nearly round, or rather as extending more from east to west than in the opposite direction. If, however, the lake Aral be considered as a part of the Caspian, from which it is separated by a sandy plain only, the greatest extent of this sea will still be from west to east.

The course of the Euphrates, of the Persio Gulf, and of almost all the rivers of China, is likewise from west to east. The rivers of the interior parts of Africa observe the same direction, running either from west to east, or from east to west. The Nile, and the rivers of Barbary, are the only ones which run from south to north. There are, it is true, large rivers in Asia, as the Don, the Wolga, &c., which partly run from north to south; but they only observe this direction in order to fall into the Black and Caspian Seas, which are lakes in the interior parts of the country.

We may, therefore, lay it down as a fact, that, in general, the rivers and Mediterranean waters of Europe, Asia, and Africa, run or stretch more from east to west than from north to south. This is a natural consequence of the

parallel direction of the different chains of mountains. Besides, the whole continent of Europe and of Asia is broader from east to west than from north to south: for the direction of mountains may be considered in two points of view. In a long and narrow continent, like that of South America, which contains only one principal chain of mountains, extending from south to north, the rivers, not being restrained by any parallel chain, must run in channels perpendicular to the range of these mountains, that is, either from east to west, or from west to east; and this, in fact, is the direction of all the great rivers in America. But though, both in the Old and New Continent, the great rivers run in the same direction, this effect is produced by different causes. The rivers, in the Old Continent, run from east to west, because they are confined by many parallel chains of mountains which stretch from west to east; but those of America observe the same direction, because there is only one chain of mountains stretching from south to north.

The rivers generally occupy the middle of the valleys, or the lowest ground between two opposite hills; if the two hills have nearly an equal declivity, the river runs nearly in the middle between them, whether the intermediate valley be broad or narrow. If, on the contrary, the declivity of one of the hills be greater than that of the other, the river will not occupy the middle of the valley, but will approach to the steepest hill, in proportion to the superiority of its de-

clivity. In this case, the middle of the valley is not the lowest ground between the two hills, but lies much nearer the steepest of them; and consequently the river must occupy that space. This observation holds universally, wherever the difference in declivity is remarkable; and the rivers never recede from the steepest hills, unless, in their course, they meet with other hills of equal declivity. In process of time, however, the declivity of the steepest hill is diminished by the rains, the melting of snow, &c. The steeper any hill is, it loses greater quantities of earth, sand, and gravel, by the operation of rains, and these substances are carried down into the plain with a proportionably greater rapidity, and, of course, force the river to change its channel, or, in other words, to retire into a lower part of the valley. It may be added, that, as all rivers occasionally swell, and overflow their banks, they carry off mud and sand, which they deposit in different parts of the valley; and, as sand and gravel are often accumulated in the channels themselves, these circumstances make the waters overflow, and alter the direction of their course. Nothing, accordingly, is more common, than to find in valleys many old channels in which the river has formerly run, especially when it is rapid, subject to frequent inundations, and carries down great quantities of sand and mud.

In plains, and extensive valleys, watered by large rivers, the channels of the rivers are commonly the lowest parts: but the surface of the water in the river is sometimes higher than the

adjacent ground. When a river, for instance, begins to overflow, it soon covers a considerable part of the plain; but the banks remain longest uncovered by the water. This circumstance plainly shows, that the banks of rivers are higher than the neighbouring ground; and that, from the banks to a certain part of the plain, there is a small declivity or slope. When, therefore, the water rises to the margin of the banks, it must be higher than the plain. This elevation of the ground on the banks of rivers is occasioned by mud and sand being deposited in the time of inundations. The water, during great swells, is always exceedingly foul and muddy: when it begins to overflow, it runs slowly over the banks, and, by depositing the mud and sand, it gradually purifies as it advances into the plain: thus, all the mud, and other substances, which are not carried down by the current, are deposited upon the banks, and gradually elevate them above the rest of the plain.

Rivers are always widest at their mouths, and turn gradually narrower towards their sources: but it is more worthy of remark, that, in the interior parts of a country, and at great distances from the sea, their course is straight, and the frequency of their windings increases proportionally as they approach to their termination. I have been informed by M. Fabry, who performed many journeys in the western parts of North America, that travellers, and even the savages, form pretty accurate computations of their distance from the sea, by observing the

courses of the rivers. If a river ran straight for fifteen or twenty leagues, they knew themselves to be a great way from the coast; but, if the sinuosities were frequent, they concluded that the sea was not very distant. M. Fabry, when travelling through unknown and uninhabited regions, derived much advantage from this observation. Near the sides of great rivers, the regorging of the water is likewise less apparent the farther from the sea, which furnishes another medium of judging concerning the distance: and, as the sinuosities multiply, the nearer rivers approach to their mouths, it is not surprising that some of them should yield to the pressure of the water, and give rise to several branches or divisions, before they reach the sea.

The motion of the water in rivers is very different from the representation given of it by mathematicians. The surface, taken from bank to bank, is not level; but the middle of the stream is either higher or lower, according to circumstances, than the water at the sides. When a river swells suddenly by the melting of snow, or any other cause, its rapidity increases; and, if its course be straight, the middle of the stream, where the current is greatest, rises and forms a sensible convexity. This elevation is sometimes very considerable. M. Hupeau, who measured this difference of level between the sides and the stream of the Aveiron, found it to be three feet. This effect must always be produced when the rapidity of the current is great; for the quickness of the motion, by diminishing, or

partly preventing the action of gravity, allows not to the water, in the middle of the stream, time sufficient to bring it to a level with that on the sides, and, therefore, it remains higher. On the other hand, near the mouths, though the current be very rapid, the water near the sides is commonly more elevated than that of the middle: the river, in this situation, has a concave form, the lowest point of which is the middle of the stream. This effect is always produced as far as the influence of the tides is perceptible, which, in large rivers, extends sometimes to 100 or 200 leagues from the sea. It is likewise a fact well known, that the streams of rivers continue their motion a considerable way through the waters of the sea. In this case, the water of the river has two opposite motions. The middle, or current, precipitates itself towards the sea; but the action of the tide produces a counter current, or regorging, which elevates the water on the sides, while that in the middle descends; and, as all the water must be carried down by the current, that on the sides constantly descends towards the middle of the stream, with a quickness proportioned to the elevation it receives from the regorging of the tide.

There are two species of regorging, or damming up, in rivers: the first is that just now described, and is occasioned by the action of the tide, which not only opposes the natural descent of the water, but even communicates to it a contrary motion or current: the other is produced by an inactive cause, as a projection of

the land, an island, &c. Though this kind of regorging gives not rise to any extraordinary counter current, it often sensibly retards the progress of small boats, and produces what is called *dead water*, which observes not the natural course of the river, but turns about in such a manner as greatly obstructs the progress of vessels. These dead waters are sensibly felt in passing through the arches of a bridge, especially if the river be rapid. The celerity with which water runs, when the height or pressure is the same, increases in proportion as the diameter of the canal, through which it passes, is diminished. The celerity of a river, therefore, in passing through a bridge, increases in the inverse proportion of the width of the whole arches to the total width of the river. This increase of celerity, in passing through the arch of a bridge, is so considerable, that it pushes the water from the stream towards the banks, from which it is reflected, and sometimes forms violent eddies or whirlpools. In passing under the bridge of St. Esprit, the mariners are obliged scrupulously to keep the stream; even after leaving the bridge; for, if they allowed the boat to decline either to the right or left, it would be driven with violence against the banks, or, at least, would be forced into the whirling or dead waters, from which they would find some difficulty of escaping. When the eddy is considerable, it forms a small gulf, with a cylindrical void in the middle, round which the water turns with rapidity. This cylindrical cavity is an effect of the centrifugal force, which

makes the water endeavour to fly off from the centre of the whirlpool.

When a great swell of the river is about to happen, the watermen perceive a particular motion, which they call a *moving at the bottom*; that is, when the water at the bottom moves with an unusual velocity, which, according to them, always indicates the approach of a sudden swell. The motion and weight of the superior waters, though not yet arrived, fail not to act upon the waters in the inferior parts of the river, and to communicate motion to them: for a river, in some respects, must be considered as a column of water contained in a tube, and its channel as a long canal, in which every motion must be communicated from one end of it to the other. Now, independent of the motion of the superior waters, their weight alone may increase the celerity of the river, and perhaps make it move quickest at the bottom; for it is well known, that, when several boats are at once pushed into a river, they increase the motion of the water below, and retard that of the superior water.

The celerity of running waters is not in exact proportion to the declivity of their channels. A river with a uniform declivity, and double to that of another, ought not, it would appear, to run with more than a double celerity: but its celerity is much more quick, being sometimes triple, sometimes quadruple, &c. The celerity depends more upon the quantity of water, and the weight of the superior waters, than upon the degree of descent. In digging the bed of a river

or drain, it is unnecessary to make the descent uniform through its whole extent. A quick motion is more easily produced by making the declivity much greater at the source than at the mouth, where, like the beds of natural rivers, it is almost imperceptible, and yet they preserve their celerity, which is more or less, according to the quantity they contain; for in great rivers, even where the ground is level, the water still runs, not only with the velocity originally acquired, but with the accumulated velocity produced by the action and weight of the superior waters *. To make this matter still more plain, let us suppose the Seine from Pont-neuf to Pont-royal to be perfectly level, and to be ten feet deep; let us also suppose the bed of the river below Pont-royal and above Pont-neuf to be suddenly dried up; the waters, in this case, would run both up and down the channel, till their equilibrium was perfectly restored. This effect is produced solely by the weight of the water, which never allows it to remain at rest till its particles are equally pressed on all sides, and its surface reduced to a perfect level. The weight of water, therefore, contributes greatly to increase the celerity of its motion. This is the reason why the greatest celerity in a current

* By not attending to these circumstances, M. Khun was led falsely to affirm, that the source of the Danube was at least two German miles higher than its mouth; that the Mediterranean is 6¼ German miles lower than the sources of the Nile; that the Atlantic Ocean is half a mile lower than the Mediterranean, &c.

of water is neither at the bottom nor at the surface, but nearly in the middle, which is pressed both by the column above, and by the reaction from the bottom. But, what is still more, when a river acquires a great celerity, it will not only preserve it, though running through a level country, but even surmount heights, without spreading much, to a side, or, at least, without producing an inundation of any moment.

One would be apt to imagine, that bridges, and other obstacles erected in rivers, would create a considerable diminution of celerity in their whole course. But the difference is very small. The water, upon meeting with any obstacle, rises, in order to surmount it; and the increase of celerity communicated by its fall, nearly compensates the retardation occasioned by the obstacle. Thus, sinuosities, projections from the land, and islands, create but a small variation on the total celerity of a river's course. The most considerable alterations are produced by the greater or lesser quantities of water; when the quantity is small, a river runs slow, when great, it runs with rapidity.

If rivers were always equally full, to enlarge their channels would be the best method of diminishing their rapidity, and to contain them within their banks. But, as almost all rivers rise and fall, it is more necessary, for this latter purpose, to narrow their channels; for small waters, with large channels, generally scoop out winding beds in the middle; and, when they swell, they follow the direction of these particular

beds, and, by striking with violence against the banks, often do much injury to mills and other works. These bad effects might be prevented, by digging gulfs in the earth at convenient distances. To accomplish this purpose, a part of one of the banks should be cut through, and the earth removed for a considerable space. These small gulfs should be made in the obtuse angles of the river; for the water, in turning, would run into them: and, of course, its celerity would be diminished. This method might be useful in preventing the fall of bridges in places where sufficient barriers cannot be erected to resist the weight of the water.

Concerning the theory of running waters, I have to add a new observation, which I made since I established mills, by which the different celerities of water may be pretty accurately ascertained. These mills are composed of nine wheels, some of which are impelled by a fall of water of two or three feet, and others by a fall of five or six feet high: I was at first surprised to find, that all the wheels turned more quickly in the night than in the day, and that the difference was greater in proportion to the height and breadth of the column of water. For example, if the water falls six feet, the wheel will turn a tenth, and sometimes a ninth quicker in the night than in the day; and, if the fall is less high, the difference of celerity will likewise be less; but it is always so sensible as to be easily recognised. I ascertained this fact by placing white marks upon the wheels, and reckoning the

number of revolutions in equal times, both during the day and the night; and I uniformly found, by a great number of observations, that the time when the wheels moved with the greatest celerity was the coldest hour of the night, and that they moved slowest when the heat of the day was greatest. In the same manner, I afterwards found, that the celerity of all the wheels is greater in winter than in summer. These facts, which have escaped the observation of philosophers, are of importance in practice. The theory of them is extremely simple: this augmentation of celerity depends solely on the density of the water, which is increased by cold and diminished by heat: and, as the same volume of water only can pass by the trough, this volume, which is denser in winter and during the night, than in summer or in the day, acts with more force on the wheel, and, of course, communicates to it a greater quantity of motion. Thus, *cæteris paribus,* there will be less loss of water, if we stop the machines during the heat of the day, and work them during the night. By observing this method in my forges, its influence in the process of making iron amounted to one twelfth part.

Another observation merits attention: of two wheels, the one nearer the canal than the other, but perfectly equal in every other respect, and both moved by an equal quantity of water, the wheel nearest the canal moves quicker than the one more remote, and to which the water cannot arrive till after it has run over a certain space in the particular runner that terminates in this

wheel. It is well known, that the friction of water on the sides of a canal diminishes its celerity. But this circumstance is not sufficient to account for the considerable difference in the motion of these two wheels. It is owing, in the *first* place, to the water in this canal not being pressed laterally, as it is when it enters by the trough of the canal, and to its striking immediately the ladles of the wheel. *Secondly*, This inequality of motion, depending on the distance of the wheels from the canal, is likewise owing to the water, which passes through a trough, not being a column of equal dimensions with the trough; for the water, in its passage, forms an irregular cone, which is depressed on the sides in proportion to the breadth of the volume of water in the canal. If the ladles of the wheel are very near the trough, the water acts very near as high as the aperture of the trough: but, if the wheel is more distant from the canal, the water sinks in the runner, and strikes not the ladles of the wheel at the same height, nor with equal celerity, as in the first case. The union of these two causes produces that diminution of celerity in wheels which are distant from the canal.

The manner in which inundations are produced, merits particular attention. When a river swells, its celerity uniformly increases, till it begins to overflow the banks: from that moment its rapidity is checked, which is the reason why inundations always continue several days; for, though the quantity of water should be

diminished after the commencement of the inundation, it would, notwithstanding, continue to overflow; because this circumstance depends more on the celerity than on the quantity of water. If it were otherwise, rivers would often overflow their banks for an hour or two, and then retire to their channels, which never happens. An inundation, on the contrary, always lasts some days, although the rains have ceased, and less water runs in the river; because the overflowing of waters diminishes their celerity; and, consequently, although the same quantity of water arrives not in the same time as formerly, the effect is the same as if a larger quantity had been brought down. It may likewise be here remarked, that, if a high wind blows contrary to the current of the river, the inundation will be increased by this occasional cause, which diminishes the celerity of the water; but, if the wind blows in the direction of the current, the inundation will be less, and retire more quickly.

"The inundation of the Nile," says M. Granger,* "has long been a subject of discussion among the learned. Most of them have considered it as a singular and wonderful phænomenon, though nothing be more natural or more common; for it takes place in every country, as well as in Egypt. The inundation of the Nile is occasioned by the rains which fall in Ethiopia and Abyssinia; but the north wind may be regarded as the principal cause of it: 1. Because the north wind drives the clouds which contain this rain into Abyssinia: 2. Be-

cause it prevents the water from running out of the mouths of the river in any great quantity, by damming up the stream. The great effect of this wind may be remarked every season, for, when it changes from north, the Nile loses more water in one day than in four *."

Inundations are generally greatest in the superior parts of rivers: because, as formerly observed, the velocity of a river uniformly increases till it empties itself in the ocean Father Castelli, a sensible writer on this subject, remarks that the banks, raised for the purpose of keeping the Po from overflowing, gradually diminish in height, as the river approaches to the sea; that, at Ferrara, which is 60 or 70 miles from the mouth of the river, the banks are about 20 feet above the ordinary level of the water; but that, at 10 or 12 miles from the sea, though the channel be equally narrow as at Ferrara, they are not above 12 feet †.

In fine, the theory of running waters is subject to many difficulties. It is not easy to give general rules which will apply to every particular case. For this purpose, experience is preferable to speculation; it is not enough that we know the common effects of rivers in general; but, if we would reason justly, and give stability to our labours, we ought to study the peculiarities of particular rivers in which we have an interest. Though the remarks I have made be

* Voyage de Granger. Paris, 1745.

† See Racolta d'atouri che trattano del moto dell'acque, vol. i. p. 128.

generally new, a greater collection is necessary. Perhaps we shall in time acquire a distinct knowledge of this subject, and be enabled to give certain rules for directing and confining rivers in such a manner as will prevent the destruction of bridges, banks, and other damages occasioned by the impetuosity of the waters.

The greatest rivers of Europe are, the Wolga, the course of which, from Reschow to Astracan on the Caspian Sea, is about 650 leagues; the Danube, which runs about 450 leagues, from the mountains of Switzerland to the Black Sea; the Don, the course of which, from the source of the Sosna, which receives it, to the Black Sea, is 400 leagues; the Nieper, which likewise falls into the Black Sea, after running 350 leagues; the Duine, which empties itself in the White Sea, runs a course of about 300 leagues, &c.

The greatest rivers of Asia are, the Hoanho, in China, which rises at Raja-ribron, and after running 850 leagues falls into the middle of the gulf of Changi, in the Chinese Sea; the Jenisca, which runs from Lake Selinga to the northern sea of Tartary, a course of about 800 leagues; the Oby, the course of which, from Lake Kila to the North Sea beyond Waigat's Straits, is about 600 leagues; the river Amour, in East Tartary, has a course of 575 leagues, from the head of the river Kerlon, which falls into it, to the sea of Kamtschatka; the river Menancon may be measured from the source of the Longmu, which falls into it, to its mouth at Poulo-condor; the Kian, the course of which is about

550 leagues, from the source of the Kinxa, which it receives, to its termination in the sea of China; the Ganges, which has a course nearly of the same extent with the Kian; the Euphrates, computing from the source of the Irma, which it receives, runs about 500 leagues; the Indus, which runs about 400 leagues, and falls into the Arabian Sea on the east of Guzarat; and the Sirderoias, which runs about 400 leagues, and falls into Lake Aral.

The greatest rivers of Africa are, the Senegal, the course of which, comprehending the Niger, which is a continuation of it, and the source of the Gombarou, which falls into the Niger, is about 1,125 leagues; the Nile, which rises in Upper Ethiopia, runs about 970 leagues. There are others, the courses of which are but partially known, as the Zaira, the Coanza, the Couama, and the Quilmanci, each of which we are acquainted with to the extent of 400 leagues.

Lastly, in America, the river of the Amazons runs more than 1,200 leagues, if we reckon from the lake near Guanuco, 30 leagues from Lima, where the Maragnon rises; or even computing from the source of the river Napo, near Quito, the course of the Amazons is more than 1,000 leagues *.

The course of the river St. Lawrence in Canada is more than 900 leagues, computing from its mouth to Lake Ontario, from that to Lake Huron, Lake Superior, Lake Alemipigo, Lake Christinaux, and the lake of the Assiniboils, the

* See Voyage de Condamine, p. 15.

waters of all which fall into one another, and at last into the river St. Lawrence.

The river Missisippi runs more than 700 leagues, from its mouth to any of its sources, which are not far from the lake of the Assiniboils.

The river Plata extends more than 800 leagues, from its mouth to the source of the Parana, which it receives.

The river Oronoko runs more than 575 leagues, reckoning from the source of the river Caketa, near Pasto, which partly falls into the Oronoko, and partly runs towards the river of the Amazons*.

The Madera, which falls into the Amazons, extends more than 660 leagues.

In order to compute the quantity of water discharged into the sea by all the rivers, we shall suppose, which is nearly the truth, that one half of the earth's surface is sea, and the other half dry land: we shall likewise suppose the mean depth of the sea to be about 230 fathoms. The total surface of the earth is 170,981,012 square miles, and that of the sea is 85,490,506 square miles, which being multiplied by one fourth, the depth of the sea, gives 21,372,626 cubic miles for the quantity of water contained in the whole ocean. Now, to compute the quantity discharged into the ocean by the rivers, let us take a river, the velocity and quantity of whose waters are known; the Po, for ex-

* See M. Condamine's Map.

ample, which passes through Lombardy, and waters a country of 380 miles in length. According to Riccioli, the breadth of the Po, before it divides into branches, is 100 perches of Boulogne, or 1,000 feet; and its depth is 10 feet; and it runs at the rate of 4 miles in an hour: consequently the Po discharges into the sea 200,000 cubical perches of water in an hour, or 4,800,000 in a day. But a cubic mile contains 125,000,000 cubic perches; of course, it will require 26 days to discharge into the sea a cubic mile of water. It only remains to determine the proportion that the Po bears to all the rivers of the earth taken together, which cannot be done exactly. But, to approach nearly to the truth, let us suppose that the quantity of water which the sea receives from the great rivers in every country, is proportioned to the extent of the surfaces of these countries; and, consequently, that the country watered by the Po, and by the rivers which fall into it, is to the total surface of the dry land as the Po is to all the rivers of the earth. Now, by the most exact charts, it appears that the Po, from its origin to its mouth, traverses a country of 380 miles in length; and the rivers which fall into it on each side arise from sources which are about 60 miles distant from the Po. Thus the Po, and the rivers it receives, water a country 380 miles long, and 120 broad, which makes 45,600 square miles. But the surface of the dry land is 85,490,506 square miles; consequently, the quantity of water carried to the sea by all the

rivers will be 1,874 times greater than the quantity discharged by the Po. But, as 26 rivers, equal to the Po, furnish a cubic mile of water each day, it follows, that, in the space of a year, 1,874 rivers equal to the Po, will carry to the sea 26,308 cubic miles of water; and that in 812 years, all these rivers would discharge 21,372,626 cubic miles, which is a quantity equal to what is contained in the ocean; of course, if the ocean were empty, 812 years would be necessary to fill it by the rivers*.

It is a result of this calculation, that the quantity of water raised from the sea by evaporation, and transported upon land by the winds, is from 20 to 21 inches in the year, or about two thirds of a French line each day. This evaporation, though tripled to make allowance for what falls back into the sea from the clouds, is very inconsiderable. Mr. Halley † has clearly demonstrated, that the vapours transported from the sea, and discharged upon the land, are sufficient to maintain all the rivers and lakes in the world.

After the Nile, the Jordan is the largest river in the Levant, or even in Barbary. It discharges each day into the Dead Sea about 6,000,000 of tons. All this water, and more, is carried off by evaporation; for, according to Halley's calculation of 6,914 tons evaporated from each superficial mile, the Dead Sea, which is 72 miles long, and 18 broad, must lose every day, by

* See Keil's Examination of Burnet's Theory, p. 126.

† See Phil. Trans. num. 192.

evaporation, near 9,000,000 of tons; that is, not only all the water it receives from the Jordan, but from the smaller rivers which come from the mountains of Moab, and elsewhere. Of course, this sea has no occasion to communicate with any other by subterraneous passages *.

The most rapid of all rivers are, the Tigris, the Indus, the Danube, the Yrtis in Siberia, the Malmistra in Cilicia, &c †. But, as was formerly remarked, the velocity of rivers depends both on the declivity and the weight of water. In examining the globe, we find that the Danube has less declivity than the Po, the Rhine, or the Rhone; for the course of the Danube is longer, and it falls into the Black Sea, which is higher than the Mediterranean, and perhaps than the ocean.

Great rivers, in their course, are constantly receiving small ones into their channels. The Danube, for example, receives more than 200 brooks and rivulets. But if we reckon only rivers of some consideration, we will find, that the Danube receives 30 or 31, the Wolga 32 or 33, the Don 5 or 6, the Nieper 19 or 20, the Duine 11 or 12. The Hoanho, in Asia, receives 34 or 35 rivers, the Jenisca more than 60, the Oby an equal number, the Amour about 40, the Kian, or river Nankin, 30, the Ganges more than 20, the Euphrates 10 or 11, &c. In Africa, the Senegal receives more than 20 rivers; the Nile receives none lower than 500 leagues from its

* See Shaw's Travels.

† See Varenii. Geog. p. 178.

mouth, the last which falls into it being the Maraba; and from this place to its source it receives about 12 or 13. In America, the Amazons receives more than 60 considerable rivers, St. Lawrence about 40, reckoning those which fall into the lakes, the Missisippi more than 40, the Plata above 50, &c.

Upon the surface of the earth, there are elevated countries which seem to be points of partition marked out by nature for the distribution of the waters. In Europe, one of these points is Mont Saint-Gothard, and its environs. Another point is the country situated between the provinces of Belozera and Wologda in Muscovy, from which many rivers descend, some into the White Sea, some into the Black, and others into the Caspian. In Asia there are several points of partition, as the country of the Mogul Tartars, some of whose rivers run into the sea of Nova Zembla, others into the gulf of Linchidolin, others into the sea of Corea, and others into that of China and the Lesser Thibet, the rivers of which run into the Chinese Sea, into the gulf of Bengal, the gulf of Cambaia, and the Lake Aral. The province of Quito, in America, discharges its rivers into the South and North Seas, and into the gulf of Mexico.

In the Old Continent, there are about 430 rivers which directly fall either into the ocean, or into the Mediterranean and Black Seas. But, in the New Continent, we know of only 136 rivers which fall immediately into the sea. In

this number I have reckoned none which are not as large as the river Somme in Picardy.

All these rivers transport from the countries through which they pass, into the sea, great quantities of mineral and saline particles. The particles of salt, which dissolve in water, are easily carried down to the sea. Several philosophers, and particularly Halley, have alleged, that the saltness of the sea proceeds alone from the particles of salt transported by the rivers: others maintain, that this saltness was coëval with the sea itself, and that the salt was created to prevent the waters from corrupting. But the agitation of the sea by the winds and the tides is, I imagine, a cause equally powerful as the salt in preserving it against putrifaction; for, when barrelled up, it corrupts in a few days. And Boyle informs us of a navigator who was overtaken with a calm which lasted 13 days, and who assured him, that the water became so putrid, that, if the calm had continued much longer, the whole crew would have perished*. Sea water is also impregnated with a bituminous oil, which renders it both unwholesome and disagreeable to the taste. The quantity of salt in sea water is about a fortieth part, and it is nearly of an equal saltness at the surface and at the bottom, under the Line and at the Cape of Good Hope; though there are some particular places, as off the Mosambique coast, where it is more salt than

* See Boyle, vol. iii. p. 222.

in others*. It is likewise said to be less salt within the arctic circle: but this phænomenon may proceed from the immense quantities of snow, and the large rivers which fall into these seas, and from the proportional defect of evaporation.

However this matter stands, I believe, that the saltness of the ocean is not only occasioned by the many banks of salt at the bottom of the sea, and along the coasts, but likewise by the salts continually brought down by the rivers; that Halley was right in his conjecture that there was originally little or no salt in the sea, but that its saltness gradually augmented in proportion as salt was supplied by the rivers; that the degree of saltness is perpetually increasing; and, consequently, that, by computing the total quantity of salt carried down by the rivers, we might be enabled to discover the real age of the world. Mr. Boyle affirms, on the authority of divers and pearl-fishers, that the water is colder in proportion to its depth; and that, at great depths, the cold becomes so excessive as to oblige them to come up much sooner than usual. But the weight of the water may be as much the cause of their uneasiness as the intenseness of the cold, especially when they descend 300 or 400 fathoms. Divers, however, seldom go deeper than 100 feet. The same author relates, that, in a voyage to the East Indies, when they arrived at the 35th degree of south latitude, they

* See Boyle, vol. iii. p. 217.

sounded to the depth of 400 fathoms, and when the lead, which weighed about 30 pounds, was drawn up, it had become as cold as ice. It is likewise a common practice at sea to sink the bottles several fathoms, in order to cool their wine; and it is said, that the deeper the bottles are sunk, the cooler the wine becomes.

These facts would lead us to imagine, that the sea water was salter at the bottom than at the surface. But they are opposed by facts of a contrary nature: experiments have been made with vessels which opened only at a certain depth, and the water was not found to be salter than that at the surface: there are even examples of the water at the bottom being fresher than at the surface: this phænomenon is exhibited in all those places where springs arise from the bottom of the sea, as near Goa, at Ormus, and in the sea of Naples, in which there are many warm springs.

In other places, sulphureous springs and beds of bitumen have been discovered at the bottom of the sea; and, upon land, there are numerous springs of bitumen which run into the sea. At Barbadoes, there is a fountain of bitumen which runs from the rocks into the sea. Bitumen and salt, then, are the principal ingredients in sea water. But it is blended with many other substances; for its taste differs considerably in different parts of the ocean: besides, agitation and the heat of the sun change the natural taste of sea water; and the different colours of different seas, and even of the same sea at different times,

prove it to be mixed with many heterogeneous bodies, which are detached either from the bottom, or carried down by the rivers.

On this subject there are two opinions, and both of them are partly true. Halley attributes the saltness of the sea solely to the salts of the earth carried down by the rivers; and even supposes that the antiquity of the world may be discovered by the degree of saltness in the waters of the ocean. Leibnitz, on the contrary, believes, that the globe having been liquified by fire, the salts and other empyreumatic substances produced with the aqueous vapours a salt lixivium, and, consequently, that the sea received its saltness from the beginning. The opinions of these two great philosophers, though opposite, should be united, and may even coincide with my own. It is extremely probable, that, at the beginning, the action of fire, combined with that of water, dissolved all the saline substances on the surface of the earth; and, of course, that the first degree of saltness in the sea proceeded from the cause assigned by Leibnitz; but this prevents not the second cause, assigned by Halley, from having considerable influence upon the actual degree of saltness in the sea, which must always augment, because the rivers incessantly carry down great quantities of fixed salts, which cannot be abstracted by evaporation. They remain, therefore, mixed with the general mass of waters, which are, in general, more salt in proportion to their distance from the mouths of rivers, and where the heat of the [illegible]

duces the greatest evaporation. That the second cause acts more powerfully than perhaps the first, is proved by this circumstance, that all lakes from which rivers issue are not salt, but almost all those which receive rivers and discharge none, are impregnated with salt. The Caspian Sea, Lake Aral, the Dead Sea, &c., owe their saltness solely to the salts transported thither by the rivers, and which cannot be carried off by evaporation.

Most countries that are furnished with large rivers are subject to periodical inundations; and those rivers which have long courses overflow with the greatest regularity. Every body has heard of the inundations of the Nile, the waters of which, though spread over a large track of country, and at a great distance from the sea, preserve their sweetness and transparency. Strabo and other ancient authors tell us, that the Nile had seven mouths; but now only two which are navigable remain: a third canal, indeed, supplies the cisterns of Alexandria; and there is a fourth, which is still less considerable. As the cleaning of these canals has long been neglected, they are mostly in ruins. In these works the ancients employed annually a vast number of workmen and soldiers, who carried off the mud and sand which this river brings down in great quantities. The overflowing of the Nile is occasioned by the rains which fall in Ethiopia: they begin in April, and end not till September. During the first three months, the days are serene and beautiful; but the sun no sooner sets, than

the rains begin, continue incessantly till sun-rising, and are commonly accompanied with thunder and lightning. The inundation in Egypt begins about the 17th of June; it generally takes 40 days in swelling, and as many in subsiding. The whole flat country of Egypt is overflowed: but the inundation is not now so great as in ancient times; for Herodotus affirms, that the Nile swelled 100 days, and required an equal time to subside. If this fact be true, the difference can be ascribed to no other causes but the gradual elevation of the land by the mud brought down and deposited, and the diminution in the height of the mountains from which this river derives its source. It is natural to think that the height of the mountains is diminished; for the heavy rains that fall in these regions during one half of the year, bring down great quantities of sand and earth from the tops of the mountains into the valleys, from which they are transported by torrents into the channel of the Nile, and are partly deposited on the land by the inundations.

The Nile is not the only river that has regular and annual overflowings: the Pegu, which is equally regular in its inundations, has, from this circumstance, got the name of the *Indian Nile*. It overflows the country for 30 leagues beyond its banks, and, like the Nile, leaves great quantities of mud and slime, which enrich the ground so much, that it produces excellent pasture for cattle, and enables the inhabitants to

export rice*. The Niger, or, which is the same thing, the upper part of the Senegal, overflows and covers the whole flat country of Nigritia. Its inundations, like those of the Nile, begin about the middle of June, and increase for forty days. The Plata, in Brazil, overflows annually, and at the same time with the Nile. The Ganges, the Indus, the Euphrates, and some other rivers, produce annual inundations. But all rivers are not subject to periodic inundations: these proceed from a combination of causes, which, at the same time, augment the quantity of water, and diminish its velocity.

We formerly remarked, that the declivity of rivers gradually diminishes till they arrive at the sea. But, in some places, the declivity is more sudden, and forms what is called *a cataract*, which is nothing more than an unusually rapid fall of the water. In the Rhine, for example, there are two cataracts, one at Bilefeld, and the other near Schafhouse. The Nile has several cataracts: two of the most remarkable fall from a great height between two mountains. In the Wologda, in Muscovy, there are also two, near Ladoga. The Zaire, a river in Congo, commences with a large cataract, which falls from the top of a mountain. But the most celebrated cataract is that of the river Niagara in Canada: it falls, in a prodigious torrent, 156 feet of perpendicular height, and is a fourth part of

* See Les Voyages d'Ovington, tom. ii. p. 290.

a league in breadth. The vapour of the water rises to the clouds, is seen at the distance of five leagues, and, when the sun shines above it, exhibits a beautiful rainbow. Below this cataract, the whirlpools and commotions of the waters are so tremendous, as to render navigation impracticable for six miles: and immediately above the cataract, the river is much narrower than higher up *.

I have since been informed †, that there is a cataract in Europe, which falls from a height of 300 feet. It is that of *Terni*, a small village on the road from Rome to Bologna. It is formed by the river Velino, which derives its source from the mountains of Abbruzzo. After passing by *Riette*, a village on the frontier of the kingdom of Naples, it falls into the Lac de Luco, which seems to be supplied by abundant sources; for the river runs out of it with more force than it enters, and proceeds to the foot of the mountain *del Marmore*, from which it is precipitated by a fall of 300 feet. It is received by a kind of abyss, from which it escapes with great tumultuousness. The celerity of its fall breaks the water with such force against the rocks and the bottom of the abyss, that a humid vapour arises, in which many rainbows of various sizes are formed by the rays of the sun; and, when the south wind blows, and drives this mist against

* See Phil. Trans. Abridg. vol. vi. part ii. p. 119.

† Note communicated to M. de Buffon by M. Fresnoye.

the mountain, instead of several small rainbows, the whole cascade is crowned with a very large one.

Charlevoix * describes the fall of the Niagara in the following manner:

"My first care, after my arrival, was to visit the noblest cascade, perhaps, in the world; but I presently found the Baron de la Hontan had committed such a mistake with respect to its height and figure, as to create a suspicion that he had never seen it. If, however, you measure its height by that of the three mountains you are obliged to climb to get at it, it does not fall much short of what the map of M. Deslisle makes it, that is, 600 feet. He has probably adopted this paradox, either on the faith of the Baron de la Hontan, or of Father Hennepin. But, after I arrived at the summit of the third mountain, I observed, that in the space of three leagues, which I had to walk before I came to this piece of water, though you are sometimes obliged to ascend, you must yet descend still more; a circumstance to which travellers seem not to have sufficiently attended. As it is impossible to approach it but on one side, and consequently to see it, except in profile, it is no easy matter to measure its height with instruments. It has, however, been attempted by means of a pole tied to a long line, and, after many trials, it has been found to be only 115, or 120 feet high.

* Tom. iii. p. 353.

But it is impossible to be sure that the pole has not been stopt by some projecting rock; for, though it was always drawn up wet, as well as the end of the line to which it was tied, this circumstance proves nothing, as the water which precipitates itself from the mountain, rises very high in foam. For my own part, after having examined it on all sides, where it could be viewed to the greatest advantage, I am inclined to think that we cannot allow it to be less than a hundred and forty or fifty feet high.

"As to its figure, it resembles that of a horse-shoe, and is about 400 paces in circumference. It is divided into two, exactly in the middle, by a very narrow island, half a quarter of a league long. It is true, these two parts very soon unite; that on my side, and which I could have a side view of only, has several branches which project from the body of the cascade, but that which I viewed in front, appeared to me quite entire. The Baron de la Hontan mentions a torrent, coming from the west, which, if this author has not invented it, must certainly fall through some channel during the melting of the snows only."

Three leagues from Albany, in the province of New York, there is a cataract of 50 feet perpendicular height, the vapour of which likewise gives rise to a rainbow *.

In every country where the number of men is too inconsiderable for forming and supporting polished societies, the surface of the earth is

* See Phil. Trans. Abridg. vol vi. part ii. p. 119.

more unequal and rugged, and the channels of rivers are more extended, irregular, and often interrupted by cataracts. The Rhone and the Loire would require the operation of several ages before they became navigable. It is by confining and directing the waters, and clearing the bottoms of rivers, that they acquire a fixed and determinate course. In thinly inhabited regions, nature is always rude, and sometimes deformed.

Some rivers lose themselves in the sands, and others seem to precipitate into the bowels of the earth. The Guadalquiver in Spain, the river of Gottenburg in Sweden, and even the Rhine, disappear under ground. It is affirmed, that, in the west part of the island of St. Domingo, there is a pretty high mountain, at the foot of which are several large caverns that receive the rivers and brooks; and the noise of their fall is heard at the distance of seven or eight leagues *. The number of rivers, however, which disappear in the earth, is very small; and they seem not to descend very deep. It is more probable, that, like the Rhine, they lose themselves by dividing and dispersing through a large surface of sand, which is very common with those small rivers that run through dry and sandy ground, of which there are many examples in Africa, Persia, Arabia, &c.

The rivers of the north carry down to the sea prodigious quantities of ice, which, by accu-

* See Varen. Geogr. p. 43

mulating, form those enormous masses, so dangerous to the mariner. The Straits of Waigat, which is frozen during the greatest part of the year, is most remarkable for these masses of ice, that are constantly brought into the straits by the river Oby.. They attach themselves all along the coasts, and rise to great heights. The middle of the strait freezes last, and the ice, of course, does not rise so high as on each side. When the north wind ceases, and it blows in the direction of the straits, the ice begins to melt and to break in the middle; then large masses are detached and transported into the open sea. The wind, which blows during the whole winter from the north, over the frozen country of Nova Zembla, renders the regions watered by the Oby, and all Siberia, so cold, that, at Tobolski, in the fifty-seventh degree, there are no fruit trees, though at Stockholm, in Sweden, and even in higher latitudes, they have fruit trees and leguminous plants. This difference proceeds not, as has been imagined, from the sea of Lapland being colder than that of the straits, nor from the country of Nova Zembla being colder than that of Lapland, but from this circumstance alone, that the Baltic and the sea of Bothnia soften the rigour of the north wind; whereas, in Siberia, there is nothing to check its activity. This solution is a result of experience. The cold is never so intense near the sea-coasts as in the interior parts of a country. There are plants which endure the open air all winter at London, which cannot be preserved at Paris; and Sibe-

ria, which is a vast continent, is, for this reason, colder than Sweden, which is almost surrounded by the sea.

Spitzbergen is the coldest country in the world: it runs as far as the seventy-eighth degree of north latitude, and is composed of small, pointed mountains. These mountains consist of gravel, and of flat stones, like gray slate, heaped upon one another. According to the accounts of voyagers, these hills are raised by the winds, and new ones appear every season. In this country no quadrupeds live but the rein deer, which feeds upon moss *. Beyond these hills, and above a league from the sea, the mast of a ship was lately found with a pully fixed to one end of it; from which circumstances, it has been concluded, that this is a new country, and that it was formerly covered with the sea: it is uninhabited and uninhabitable; for the hills have no consistence, but are loose and moveable; and a vapour proceeds from the earth, so cold and penetrating, as to preclude the possibility of remaining any time upon this dreary and inhospitable land.

The whale-fishing vessels arrive at Spitzbergen in July, and depart from it about the middle of August. The ice permits them not to arrive sooner, or to remain longer. In these seas there are prodigious islands of ice, clear and shining as

* The arctic fox, and a small animal larger than a weesel, with short ears, long tail, and spotted with black and white, likewise inhabit Spitzbergen. W.

glass, and from sixty to eighty fathoms thick; and, in some places, the sea appears to be frozen to the bottom *.

The seas of North America are likewise much infested with ice, as in Ascension Bay, in Hudson's, Cumberland's, Davis's, and Frobisher's Straits, &c. We are assured by Robert Lade, that the mountains of Friesland are entirely covered with snow; and that the ice surrounds the coasts, and, like a bulwark, prevents all approach to them. "It is remarkable," says he, "that in this sea, we meet with islands of ice, more than half a league in circumference, exceedingly high, and descend from seventy to eighty fathoms deep. This ice, which is sweet, is perhaps originally formed in the rivers or straits of the adjacent lands, &c. These islands or mountains of ice are moveable, and, in storms, they follow the tract of a ship, as if they were drawn after her by a rope. Some of them rise so high above the water, that they surmount the tops of the tallest masts †," &c.

In the voyages collected for the use of the Dutch East India Company, we have the following account of the ice off Nova Zembla: "At Cape Troost, the weather was so foggy as to oblige us to moor our vessel to a bank of ice, which was thirty-six fathoms below, and sixteen above the surface of the water. On the 10th of August, the ice began to separate, and to

* See Recueil des Voyages du Nord, tom. i. p. 154.

† See Lade's Voyages.

float; we then remarked, that the mass to which our vessel had been moored, touched the bottom; for, though the others were all in motion, and struck against it, and against each other, it remained immoveable. We were now afraid of being frozen in, or dashed to pieces; we, therefore, endeavoured to escape from this latitude, though the vessel, in her course, was obliged to push through the ice, which made a great noise round us for a considerable distance: we at last anchored along another island of ice, where we remained that night.

"During the first watch, the ice began to split, with an inconceivable noise. The ship's head kept so strongly to the current in which the ice floated, that we were obliged to veer the cable in order to get her off. We counted above 400 blocks of ice, which sank ten fathoms below the water, and appeared to rise about two fathoms above it.

"We then moored the vessel to another block of ice, which was immersed below the surface about six fathoms. At a little distance from this station we perceived a large bank, which was pointed like a cone, and reached to the bottom of the sea: we approached it, and found it to be twenty fathoms below, and about twelve above the surface of the water.

"On the 11th, we sailed up to another bank, which was eighteen fathoms below the surface, and ten fathoms above it.

"The Dutch, on the 21st, advanced a great

way between the boards of ice, and anchored during the night. Next morning they retired, and moored to a bank which was eighteen fathoms below, and ten above the water. They climbed to the top, and remarked, as a singular phænomenon, that it was covered with earth, and that they found there about forty eggs. Its colour was a fine azure blue, and totally different from that of the other masses. This circumstance gave rise to various speculations; some imagining it to be an effect of the ice, and others thought the whole was a mass of frozen earth *."

Wafer met with many floating pieces of ice, off Terra del Fuego, which were so large that he at first imagined them to be islands: some of them, he remarks, appeared to be a league or two in length, and the largest of them seemed to rise 400 or 500 feet above the surface of the water.

All these masses of ice, as I have remarked in the 6th article, are transported from the rivers into the sea. Those in the sea of Nova Zembla and in the Straits of Waigat, come from the Oby, and, perhaps, from the Jenisca, and other great rivers in Siberia and Tartary; those of the Hudson's Straits, from Ascension Bay, into which many rivers in North America empty themselves; and those of Terra del Fuego, from the southern continent. If

* See Troisieme Voyage des Hollandois par le Nord, tom. i. p. 46.

fewer of them appear in the northern coasts of Lapland than in those of Siberia and Waigat's Straits, it is because all the Lapland rivers fall into the gulf of Bothnia, and none of them into the North Sea. They may likewise be formed in straits, where the tides rise higher than in the open sea; and, consequently, where the islands of ice which float on the surface may accumulate and produce masses or banks of several fathoms high. But, with regard to those which rise to the height of four or five hundred feet, it appears that they can no where be produced but near very elevated coasts; and I imagine, that when the snows which cover these coasts melt, the water runs down upon the masses of ice, and, by freezing anew, gradually augments their size, till they arrive at this amazing height; that, in a warm summer, the action of the winds, the agitation of the sea, and perhaps their own weight, may detach them from the coasts, and set them adrift; and that they may even be transported into temperate climates before they are entirely dissolved.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XI.

Of Seas and Lakes.

THE dry land is every where surrounded by the ocean; it penetrates sometimes by large openings, and sometimes by small straits, into the interior parts of different countries, and forms mediterranean seas, some of which are affected by the motion of the tides, and others not. We shall, in this article, trace the ocean through all its windings; and, at the same time, give an enumeration of the mediterranean seas, which we shall endeavour to distinguish from what are called bays or gulfs, and lakes.

The sea that washes the western coasts of France, forms a gulf between Spain and Brittany. This gulf is, by navigators, called the Bay of Biscay: it is very open, and advances farthest into the land between Bayonne and St. Se-

bastian. It likewise advances considerably at Rochelle and Rochefort. This bay begins at Cape Ortegal, and terminates at Brest, where a strait commences between the south point of Brittany and the Lizard Point. This strait, which is at first pretty wide, forms a small bay on the coast of Normandy, the most advanced point of which is at Auranche. It continues pretty large till it arrives at the channel of Calais, where it is very narrow; it then suddenly enlarges, and terminates between the Texel and the coast of Norwich: at the Texel, it forms a small shallow mediterranean, called *Zuderzee*, and several large gaps or advances, the waters of which are not of a considerable depth.

After this, the ocean forms a large bay called the *German Sea*, which commences at the northmost point of Scotland, and runs along the east coast of Britain the length of Norwich; and from thence to the Texel, along the coasts of Holland and Germany, of Jutland and Norway, as far as Bergen. This bay may even be considered as a mediterranean; for the Orkney islands nearly shut up its mouth, and seem, by their direction, to be a continuation of the mountains of Norway. It forms a large strait, which commences at the south point of Norway, and continues pretty broad to the island of Zetland, where it suddenly contracts, and forms, between the coasts of Sweden and the islands of Denmark and Jutland, four small straits; after which, it widens to a small bay, the most advanced point of which is at Lubec; from thence, to the south

extremity of Sweden, it continues pretty broad; then it enlarges more and more, and forms the Baltic, which is a mediterranean sea, extending, from south to north, near 300 leagues, if the gulf of Bothnia, which is a continuation of it, be comprehended. In the Baltic are two bays, that of Livonia, the most advanced point of which is near Mittau and Riga, and that of Finland, which is a branch of the Baltic, extending between Livonia and Finland to Petersburgh, and communicating with Lake Ladoga, and even with Lake Onega, which joins the White Sea by means of the river Onega. The whole body of water which forms the Baltic, the gulfs of Bothnia, of Finland, and of Livonia, ought to be regarded as an immense lake, supported by a great number of rivers, as the Oder, the Vistula, the Niemen, the Droine in Germany and Poland; by other rivers in Livonia and Finland; by others still more considerable which come from Lapland, as the Tornea, the Calis, the Lula, the Pithea, the Uma; and by several from Sweden. These rivers, which, in general, are large, amount to more than forty, including those which fall into them, and cannot fail to convey a quantity of water sufficient to supply the Baltic. Besides, there are no tides in the Baltic, and its water has very little saltness: and if the situation of the land, and the number of lakes and marshes in Finland and Sweden, which are contiguous to the Baltic, be taken into consideration, we shall be inclined to regard it not as a sea, but as a great lake formed by the waters which it

receives from the adjacent countries, and which have forced for themselves a passage near Denmark into the ocean, into which, according to the relation of voyagers, it still continues to run.

From the commencement of the bay, which goes by the name of the German Sea, and which terminates beyond Bergen, the ocean follows the coasts of Norway, Swedish Lapland, North Lapland, and Muscovite Lapland, at the eastern part of which it forms a large strait, and gives rise to the mediterranean called the White Sea, which may also be considered as a great lake; for it receives twelve or thirteen large rivers, which are more than sufficient to supply it with water; and its water contains but little salt. Besides, it very nearly, in several places, communicates with the Baltic; and it has an evident communication with the gulf of Finland; for, in ascending the river Onega, we arrive at a lake of the same name, which is joined by two rivers to Lake Ladoga; and this last communicates by a large branch with the gulf of Finland; and there are, in Swedish Lapland, several places from which the waters run almost indifferently either into the White Sea or into the gulfs of Bothnia and of Finland. This whole country is full of lakes and marshes, and, therefore, it seems probable, that the Baltic and White Seas were the receptacles of its waters, and that, in time, they discharged themselves into the German and Frozen Seas.

On leaving the White Sea, and coasting the island of Candenos, and the north of Russia, the

ocean advances a small arm into the land at the mouth of the river Petzora. This arm, which is about forty leagues in length, by eight or ten in breadth, may rather be regarded as a collection of water formed by the river, than as a gulf of the sea; for it also contains very little salt. In this place the land runs out in a promontory terminated by the small islands of Maurice and of Orange; and between this promontory and the neighbouring land to the south of Waigat's Strait, there is a bay of about thirty leagues long, which belongs to the ocean, and is not formed by rivers. This is succeeded by Waigat's Strait, which lies nearly under the seventieth degree of north latitude; it is not above eight or ten leagues in length, and it communicates with the sea which washes the north coasts of Siberia. As this strait is blocked up with ice during the greatest part of the year, it is very difficult to penetrate into the sea beyond it. This passage has been tried in vain by many navigators; and those who succeeded have not given us exact charts of the sea, which they call the Pacific Sea. By the most recent charts, and by the best globes, it appears, that this sea may be only a mediterranean, having no connexion with the great sea of Tartary; for it seems to be shut up and bounded to the south by the country of the Samoides, which is now well known, and which extends from the Straits of Waigat to the mouth of the river Jenisca: to the east, it is bounded by Jelmorland; to the west by Nova Zembla; and, though we know not the extent of this

sea to the north and north-east, as the land seems not to be interrupted, it is probable that the Pacific Sea is only a mediterranean; and that it is bounded by land, and has no communication on that side with the ocean. What establishes this fact is, that, in departing from the Straits of Waigat, the whole west and north coasts of Nova Zembla, the length of Cape Desire, have been traversed; that, from this Cape, the coasts of Nova Zembla have been traced to a small bay about the seventy-fifth degree, where some Dutchmen passed a dreadful winter in 1596; and that, beyond this gulf, the land of Jelmorland was discovered in 1664, which is separated from Nova Zembla only by a few leagues of land; so that the only land unknown is a small spot near this little bay just now described; and this spot exceeds not, perhaps, thirty leagues in length. If, therefore, the Pacific Sea joins with the eastern ocean, it must be by means of this small bay, which is the only way by which this mediterranean can have any communication with the Eastern Ocean. And, even on the supposition that such a communication existed, as this bay lies in the seventy-fifth degree of latitude, it would be necessary, to gain this open sea, to keep five degrees farther north. It is apparent, therefore, that, in attempting a north passage to China, it is better to sail beyond Nova Zembla to the seventy-seventh or seventy-eighth degree, where the sea is more open and clearer of ice, than to persist in passing the frozen straits of Waigat, when it is even uncertain whether the

sea beyond them has any communication with the Eastern Ocean.

The coast has been traced from Nova Zembla and Jelmorland to the mouth of the Chotanga, which is about the seventy-third degree; beyond which an unknown coast extends about 200 leagues. We only know, from the Russians who travelled by land into these climates, that the country is not interrupted; and, in their charts, the rivers are delineated, and they called the inhabitants *Populi Palati*. This interval of unknown coast extends from the mouth of the Chotanga to that of Kauvoina, in the sixty-sixth degree of latitude. The bay of Linchidolin, in which the Russians fish whales, advances farthest into the land at the mouth of the Len, which is a considerable river. This bay is very open, and pertains to the sea of Tartary.

From the mouth of the Len, the northern coast of Tartary runs about 500 leagues eastward to a peninsula inhabited by a people called Schelates. It is the most northern point of Tartary, and lies under the seventy-second degree of latitude. In this extent of 500 leagues, the ocean forms neither bays nor arms; only from the peninsula of the Schelates, to the mouth of Korvinea, there is a considerable elbow or projection. This point is the eastern extremity of the north coast of the Old Continent, and Cape North in Lapland is the western extremity. Thus, we have of northern coast from Cape North in Lapland, to the extremity of the coun-

try of the Schelates, an extent of 1,700 leagues, including the sinuosities of bays; and it measures about 1,100 leagues in a straight line.

Let us next take a survey of the eastern coasts of the Ancient Continent. We shall begin at the extreme point of the country of the Schelates, and descend towards the equator. The ocean first makes a turn between the country of the Schelates and that of the Tschutschi, which last projects considerably into the sea. To the south of this country, there is a small open bay, called the bay of Suctoikret. This bay is succeeded by another, which advances, like an arm, about forty or fifty leagues into the land of Kamtschatka: after which the ocean flows in, by a narrow strait, full of small islands, between the southern point of Kamtschatka and the northern point of the land of Jesso, and forms a large mediterranean, which we shall now describe in detail. It consists of the sea of Kamtschatka, in which there is a considerable island, called the island of *Amour*. An arm of this sea runs north-east. But both this arm and the sea of Kamtschatka may, at least in part, be formed by the rivers which flow into it from the lands of Kamtschatka, and those of Tartary. However this matter stands, the sea of Kamtschatka communicates, by a very long strait, with the sea of Corea, which is another part of this mediterranean; and the whole together, extending more than 600 leagues in length, is bounded on the west and north, by the lands of Corea and Tartary; and, on the east and south, by those of

Kamtschatka, Jesso, and Japan, without having any other communication with the ocean than by the strait between Kamtschatka and Jesso; for it is uncertain whether the communication between Japan and the land of Jesso, though laid down in some charts, has a real existence; and, even supposing it did exist, the sea of Kamtschatka and that of Corea would still be regarded as forming together a great mediterranean, separated on all sides from the ocean, and not as a bay; for it communicates not with the ocean by its southern strait, but with the Chinese Sea, which is rather a mediterranean than a bay.

The South Sea is much broader than the Atlantic, and appears to be bounded by two chains of mountains, which correspond as far as the equator. The first chain is composed of the mountains of California, of New Mexico, of the isthmus of Panama, of the Cordeliers, of Peru, of Chili, &c. The other chain stretches through Kamtschatka, Yesso, and Japan, and extends as far as the Ladrone islands, and even the New Philippines. The direction of these chains of mountains, which appear to be the ancient limits of the Pacific Ocean, is precisely from north to south; so that the Old Continent was bounded on the east by one of these chains of mountains, and the New Continent by the other. Their separation happened at the period when the waters, proceeding from the south pole, began to run between these two chains of mountains, which seem to unite, or at least to make

a very near approach to each other towards the northern regions. This is not the only indication of the ancient union of the two continents on the north. This continuity of the two continents between Kamtschatka and the most western lands of America, seems now to be proved by the new discoveries of navigators, who have found, under the same parallel of latitude, a great number of islands lying so near each other, as to leave only small intervals of sea between the east of Asia and the west of America under the polar circle.

In the preceding article, it was remarked, that the sea had a constant motion from east to west; and that, consequently, the great Pacific Ocean is making continual efforts against the eastern coasts. An accurate examination of the globe will confirm the conclusions we have drawn from this observation; for it appears, that from Kamtschatka to New Britain, discovered by Dampier in 1700, and which lies in the fourth or fifth degree of south latitude, the ocean has encroached on these coasts to the extent of 400 leagues; and, of course, that the eastern bounds of the Old Continent stretch not so far as they did formerly; for, it is remarkable, that New Britain and Kamtschatka, which are the most advanced lands to the east, lie under the same meridian. Besides, all countries extend farthest from north to south. Kamtschatka makes a point of about 160 leagues from north to south, and this point, the eastern coast of which is wahsed by the Pacific Ocean, and the other by

the mediterranean above described, is divided from north to south by a chain of mountains. The lands of Japan and of Jesso form another territory between the ocean and the sea of Corea, extending from north to south more than 400 leagues; and the direction of the chains of mountains in Jesso and Japan must be from north to south; because, in this direction, they extend 400 leagues; but, from west to east, they exceed not fifty or sixty. Thus Kamtschatka, Jesso, and the eastern part of Japan, ought to be considered as contiguous lands, lying in a direction from north to south: and, following the same direction, we find, after the point of Cape Ava in Japan, the island of Barnevelt, and three other islands, situated in a line from north to south, and extending about 100 leagues. We next meet with three islands called Callanos, and, after these, the Ladrone islands, to the number of fourteen or fifteen, all stretched in a line from north to south, the whole occupying a space of 300 leagues in length; and the broadest part of these islands, from east to west, exceeds not eight leagues. From these facts I am led to conclude, that Kamtschatka, Jesso, the east part of Japan, the islands of Barnevelt, the Callanos, and the Ladrones, are a continuation of the same chain of mountains, and the remains of an ancient country, which has been gradually corroded and covered with the sea. All these countries appear to be nothing but mountains, of which the islands are the peaks or points, the low lands being occupied by the ocean. Hence,

what is related in the *Lettres Edifiantes* must be true; and, in fact, a number of islands, called the New Philippines, have been discovered in the very situation in which P. Gobien supposed them to lie: and it cannot be doubted, that the most easterly of these New Philippines are a continuation of the chain of mountains which compose the Ladrones; for these eastern islands, to the number of eleven, lie in a line from north to the south, extending in length more than 200 leagues; and, in breadth, the largest of them exceeds not eight leagues.

But these conjectures may seem too bold, on account of the great distances between the islands in the neighbourhood of Cape Ava, of Japan, and of the Callanos, between these islands and the Ladrones, and between the Ladrones and the New Philippines, the first interval being about 160 leagues, the second fifty or sixty, and the third near 120. But it ought to be considered, that chains of mountains often extend much farther below the waters of the ocean; and that these intervals are nothing when compared to the extent of land, from south to north, in these islands or mountains, which, beginning at the interior part of Kamtschatka, is more than 1,100 leagues. But, though this idea concerning the quantity of land gained by the ocean on the eastern parts of the Old Continent, and the continuation of the mountains, should be rejected, still it must be acknowledged, that Kamtschatka, Jesso, Japan, the islands of Rois, Formosa, Vaif, Basha, Babuyane, Lucca, Mindano, Gilolo, &c.,

and, lastly, New Guinea, which extends to New Britain, and is situated under the same meridian as Kamtschatka, form a stretch of country of more than 2,200 leagues; with small interruptions, the greatest of which exceeds not, perhaps, twenty leagues; so that the ocean has scooped out an immense bay from the interior parts of the eastern continent, which begins at Kamtschatka, and terminates at New Britain. This bay is interspersed with numerous islands, and has all the appearances of being gained from the land. It is, therefore, probable, that the ocean, by its constant motion from east to west, has gradually gained this great tract of country from the continent, and has formed several mediterraneans, as those of Kamtschatka, of Corea, of China, and perhaps the whole Indian Archipelago, for the land and water are so blended together in this region, that it evidently appears to have been a large country destroyed by inundations, of which only the eminences and mountainous parts are now to be seen, the lower grounds being entirely concealed under the waters of the ocean. This hypothesis is farther confirmed by the shallowness of the sea, and the figures of the innumerable islands, which seem to be nothing but the tops of mountains.

If we take a more particular survey of these seas, we shall find, that the northern part of the Chinese Sea forms itself into a great bay, which begins at the island of Fungma, and terminates at the frontiers of the province of Pekin, about fifty leagues from this capital of the Chinese em-

pire. The most advanced and narrowest part of this bay is called the gulf of Changi. It is probable that this gulf, and part of the sea of China, are encroachments of the ocean, and that the islands above described are the most elevated parts of the ancient country. Farther south are the bays of Tonquin and of Siam, in the neighbourhood of which is the peninsula of Malacca, consisting of a long chain of mountains, that run from north to south; and the Andaman islands, which form another chain of mountains, in the same direction, seem to be only a continuation of those of Sumatra.

The ocean afterwards forms the great bay of Bengal; where it may be remarked, that the land of the peninsula of Indus makes a concave curve, towards the east, nearly resembling the great bay of the eastern continent, which seems to have been produced by the same cause, namely, the motion of the sea from east to west. In this peninsula are the mountains of Gates, which extend from north to south, and the island of Ceylon appears to have been separated from this part of the continent.

The Maldiva islands are only another chain of mountains stretching from north to south. Then follows the Arabian Gulf, which sends off four branches or arms; the two largest are on the west coasts, and the two smallest on the east. The first arm on the east coast is the bay of Cambaia, which extends not above fifty or sixty leagues; but it receives two considerable rivers, the Tapta and the Baroche or Mehi. The se-

cond arm or bay on the same coast is remarkable for the rapidity and height of its tides, which alternately advance and retreat more than fifty leagues. Into this bay fall several rivers, as the Indus, the Padar, &c., which have brought down sand and mud in such quantities as to elevate the bottom of the bay, and reduce it nearly to a perfect level. It is owing to this circumstance that the tides extend to so great a distance. The first arm on the west coast is the Persic Gulf, which advances into the land above 250 leagues; and the second is the Red Sea, which, reckoning from the island of Socotora, extends above 680 leagues. From the Straits of Ormuz and of Babelmandel, these two arms should be considered as mediterranean seas: they are both, indeed, subjected to a flux and reflux; but this circumstance is occasioned by their vicinity to the equator, where the tides rise higher than in other climates. Besides, they are both very long and very narrow. The motion of the tides is more rapid in the Red Sea than in the Persic Gulf; because the former is nearly three times as long, and equally narrow, as the latter; neither does it receive any river capable of resisting the tide: but the Persic Gulf receives three large rivers at its most advanced extremity. It is apparent, that the Red Sea has been formed by an irruption of the ocean; for the situation and similarity in the direction of the coasts on each side of the Straits of Babelmandel show, that this passage has been cut by the waters.

At the extremity of the Red Sea lies that fa-

mous strip of land called the isthmus of Suez, which is a barrier to the junction of the Red Sea with the Mediterranean. In the preceding article, I gave the reasons which render it probable that the Red Sea is higher than the Mediterranean, and that, if the isthmus were cut, an inundation and increase of the latter would be the consequence. It may here be added, that, though the superior elevation of the Red Sea should not be allowed, yet it is incontestible, that there are no tides in the Mediterranean near the mouths of the Nile. It is equally certain, that the tides in the Red Sea rise several feet; and this circumstance alone, on the supposition of the removal of the isthmus, would occasion a great influx of water from the Red Sea into the Mediterranean. Besides, Varenius, in his Geography *, remarks, " Oceanus Germanicus, qui est Atlantici pars, inter Frisiam et Hollandium se effundens, efficit sinum, qui etsi parvus sit respectu celebrium sinuum maris, tamen et ipse dicitur mare, alluitque Hollandiæ emporium celeberrimum, Amstelodamum. Non procul inde abest lacus Harlemensis, qui etiam mare Harlemense dicitur. Hujus altitudo non est minor altitudine sinus illius Belgici, quem diximus, et mittit ramum ad urbem Leidam, ubi in varias fossas divaricatur. Quoniam itaque nec lacus hic, neque sinus ille Hollandici maris inundant adjacentes agros (de naturali constitutione loquor, non ubi tempestatibus urgen-

* Page 100.

tur, propter quas aggeres facti sunt); patet inde, quod non sint altiores quam agri Hollandiæ. At vero Oceanum Germanicum esse altiorem quam terras hasce, experti sunt Leidenses, cum suscepissent fossam seu alveum ex urbe sua ad Oceani Germanici littora, prope Cattorum vicum perducere (distantia est duorum milliarium) ut, recepto per alveum hunc mari, possent navigationem instituere in Oceanum Germanicum, et hinc in varias terræ regiones. Verum enimvero, cum magnam jam alvei partem perfecissent, desistere coacti sunt, quoniam tum demum per observationem cognitum est, Oceani Germaninici aquam esse altiorem quam agrum inter Leidam et littus Oceani istius: unde locus ille, ubi fodere desierunt, dicitur *Het malle Gat*. Oceanus itaque Germanicus est aliquantum altior quam sinus ille Hollandicus," &c.

As the German Ocean, therefore, is higher than the sea of Holland, nothing prevents us from believing that the Red Sea may be higher than the Mediterranean. Herodotus and Diodorus Siculus mention a canal of communication between the Nile, the Mediterranean, and the Red Sea: and M. de l'Isle, in 1704, published a map, where he has laid down the termination of a canal in the east branch of the Nile, which he imagined to be a part of the canal which formerly joined that river to the Red Sea *. We meet with the same opinion in a book entitled *Commi-*

sance de l'Ancien Monde; where the author, copying Diodorus Siculus, informs us, that this canal was begun by Neco king of Egypt; that Darius king of Persia continued the work; that it was finished by Ptolemy II., who conducted it to the city of Arsinoa; and that it could be shut and opened at pleasure. I pretend not to deny these facts; but, I confess, they appear to be doubtful. I suspect, that the violence and height of the tides in the Red Sea, would necessarily communicate their influence to the waters of the canal: at least, it would require great precaution to prevent inundations, and to keep the canal in proper repair. Though we are told by historians that this canal was begun and finished, they are silent as to its duration; and the remains of it, which are pretended still to exist, are perhaps the only parts of it that ever were executed. This branch of the ocean has been denominated the *Red Sea,* because, wherever there are madrepores or corals at the bottom, the water of it has the appearance of being red. The following description of it is given in the *Histoire Generale des Voyages* *: "before leaving the Red Sea, D. Jean inquired into the causes which induced the ancients to give it this appellation: he recollected, that Pliny had delivered several opinions concerning the origin of this name. Some derived it from a king of that country, called *Erythros,* which, in the Greek language, signifies *Red:* others imagined that the red co-

* Tom. i. p. 198.

lour was occasioned by the reflection of the sun from the surface of the water; and others affirmed that the water itself was red. The Portuguese, who had made several voyages in that sea, alleged, that the whole coast of Arabia was remarkably red; and that the dust and sand carried into the sea by the winds tinged the water with the same colour.

" Dom Jean, who examined the nature of the water and of the coasts, through their whole extent, with the most scrupulous attention, assures us, that the waters of this sea have no peculiarity in their colour; and that the dust and sand, not being red themselves, could not possibly communicate this colour to the water. The land on each side, he observes, is generally brown; in some places, it is black, and, in others, white: at Suaquem, the coasts of which the Portuguese never visited, there are three mountains striped with red; but they consist of hard rocks, and the neighbouring ground is of the usual colour.

" The truth is, that this sea is all of the same uniform colour, of which any man may satisfy himself by drawing water from different parts. But, it must be acknowledged, that, in some places, it appears, by accident, to be red, and, in others, green and white. This phænomenon admits of the following explication. From Suaquem to Kossir, which is an extent of 136 leagues, the sea is filled with banks and rocks of coral; they are so called from their resembling coral in form and colour so exactly, that it is

difficult to perceive the distinction: there are two kinds of them, the one is white, and the other extremely red. In many places, they are covered with a kind of gum, or viscid substance, of a green colour, and sometimes of a deep orange. Now, the water of this sea is so transparent, that the bottom is visible at the depth of twenty fathoms, especially from Suaquem to the extremity of the gulf; and hence the water assumes, in appearance, the colour of the bodies which it covers. When, for example, the rocks are overlaid with a green gum, the water above them appears to be green; when the bottom is sand alone, the superincumbent water seems to be white; and, when the rocks are covered with coral, the water above them appears to be reddish. But, as the rocks of this colour are more frequent than the green or white, Dom Jean concludes, that the Arabic Gulf, has, from this circumstance, obtained the name of the Red Sea. He was the more satisfied with this discovery, because the method he employed in the investigation of it left no room for hesitation or doubt. In such places as were not deep enough to allow his vessel to sail, he fastened pinks opposite to the rocks; and the sailors were enabled to execute his orders, at more than half a league from the rocks, without being immersed above the middle of their bodies. In those places where the water appeared red, the greatest part of the stones and pebbles they brought up were of the same colour; where the water appeared green,

the stones were green also; and where the water appeared white, the bottom was a pure white sand."

From the entrance to the Red Sea, at Cape Gardafu, to the Cape of Good Hope, the direction of the coast is pretty equal, and the sea forms no bay of any note. There is, indeed, a small scoop on the coast of Melinda, which, if the island of Madagascar were united to the continent, might be considered as a part of a large bay. This island, it is true, though separated by the straits of Mozambique, appears to have formerly belonged to the continent; for, in this strait, there are high sands of great extent, especially on the Madagascar coast, which render the open part of it very narrow.

From the Cape of Good Hope to Cape Negro, on the west coast of Africa, the land lies in the same direction; and the whole of it seems to be a chain of mountains: it is, at least, a very elevated country, and, though more than 500 leagues in length, it is furnished with no rivers of any consideration, except one or two, which are known no farther than their mouths. But the coast, above Cape Negro, makes a large curve; and the land, along this curve, appears to be lower than that of the rest of Africa: it is watered by several great rivers, the largest of which are the Coanza and the Zaire. From Cape Negro to Cape Gonsalvez, are the mouths of twenty-four considerable rivers; and the space between these two capes, reckoning along the shore, is about 420 leagues. We would be tempted to

think, that the ocean has encroached on these low lands of Africa, not by its natural motion from east to west, which could have no influence in producing this effect, but by the facility with which it might have undermined and surmounted them. From Cape Gonsalvez to Cape Trois-pointes, the ocean forms an open bay, which presents nothing remarkable, except a very advanced point nearly in the middle of it, called *Cape Formosa*: it likewise contains, in the southern part of it, the islands of Fernandpo, St. Thomas, and Prince's Island. These islands appear to be a continuation of a chain of mountains situated between Rie del Rey, and the river Jamoer. From Cape Trois-pointes to Cape Palmas, the ocean runs a little in upon the land; and from Cape Palmas to Cape Tagrin, there is nothing worthy of remark. But, beyond Cape Tagrin, there is a small bay in the country of Sierra-Leona; and a little farther, there is another, in which are situated the islands of Bisagas. We afterwards meet with Cape Verd, which projects far into the sea, and of which the islands of the same name appear to be a continuation; or, rather, they seem to be a continuation of Cape Blanc, which is a more elevated country, and stretches still farther into the ocean. We next come to a mountainous and dry coast, which commences at Cape Blanc, and terminates at Cape Bajador: the Canary islands seem to be a continuation of these mountains. Lastly, between Africa and Portugal, is a large open bay, in the middle of which are the celebrated Straits of Gibraltar.

The ocean pours its waters, with great rapidity, through this strait into the Mediterranean. This sea runs into the interior parts of the land near 900 leagues, and gives rise to many objects worthy of remark. 1st, It has no perceptible tides, except in the gulf of Venice; and a small flux and reflux have been alleged to take place at Marseilles and on the coast of Tripoli. 2d, It contains many large islands, as Sicily, Sardinia, Corsica, Cyprus, Majorca, &c., and Italy, which is one of the most extensive peninsulas in the world: it is likewise adorned with a rich Archipelago, or rather, it is from the Mediterranean Archipelago that all other collections of islands have acquired that appellation. But this Archipelago appears to belong more properly to the Black Sea than to the Mediterranean; and it is probable, that the country of Greece was partly covered with the Black Sea, which runs into the sea of Marmora, and from that into the Mediterranean.

It has been alleged, that a double current runs through the Straits of Gibraltar; one superior, which carries the waters from the ocean into the Mediterranean, and another inferior, which carries the waters from the Mediterranean back to the ocean. But this notion is false, and contrary to the known laws of hydrostatics. Opposite currents have been ascribed to several other straits, as the Bosphorus, the straits of Sunda, &c.; and Marsilli has related many experiments tending to prove the existence of a superior and in-

ferior current in the Bosphorus. These experiments, however, must have been fallacious; for such a phænomenon is repugnant to the nature and motion of fluids. Besides, Greaves, in his *Pyramidographia*, has demonstrated, by accurate experiments, that there are no opposite currents in the Bosphorus. Marsilli and others may have been deceived by the regorging of the water near the shores, which takes place in the Bosphorus, in the Straits of Gibraltar, and in all rapid rivers, and which often produces a motion opposite to that of the principal current.

However, I have since received information, which seems to prove, that double currents actually exist, and can even be demonstrated, in certain parts of the sea. On this subject, M. Deslandes, an able navigator, obligingly communicated to me the following accurate remarks, in two letters, the one dated December 6, 1770, and the other November 5, 1773.

"In your *Theory of the Earth*, art. xi. *Of Seas and Lakes*, you say, that *a double current has been alleged to run through the Straits of Gibraltar; but that those who support this opinion have been deceived by the regorging of the water near the shores, which often produces a motion opposite to that of the principal current.*

"After reading this passage, I determined to transmit you my observations on the subject.

"Two months after my departure from France, I reconnoitered the land between Capes Gonsalvez and Saint Catharine. The force of the

currents, the direction of which is to the north north-west, corresponding exactly with the situation of the lands, obliged me to cast anchor. The general winds of this region blow from the south south-east, south south-west, and south-west. I spent two months and a half in making fruitless attempts to change my situation, and to reach the coast of Loango, where I had some business to transact. During this time, I remarked, that the sea descended in the above direction from half a league to a league in the hour, and that, at certain depths, the currents ascended below with the same rapidity as they descended above.

" I ascertained the depth of these opposite currents in the following manner: being moored in eight fathoms water, and the sea extremely clear, I fixed a lead of thirty pounds weight to the end of a line. At about two fathoms from the lead, I tied a table napkin to the line by one of its corners, and allowed the lead to sink in the water. As soon as the table napkin entered, it took the direction of the first current. Continuing to observe it, I made it descend. Whenever I perceived that the current discontinued, I stopped. It then floated indifferently around the line. In this place, therefore, the run was interrupted. I then sunk the table napkin about a foot lower, and it assumed an opposite direction. By marking the line at the surface of the water, I found that the table napkin was at the depth of three fathoms; from which I concluded,

after different examinations, that, of eight fathoms water, three ran north north-west, and five ran in the contrary direction of south south-east.

"The same day, I repeated the experiment in fifty fathoms water, being then distant from the land six or seven leagues. I was surprised to find that the upper current was deeper in proportion to the depth of the bottom. Of fifty fathoms water, I reckoned that from twelve to fifteen ran in the first direction. This phænomenon did not take place during the whole two months and a half that I remained on this coast, but nearly one month only, and at different times; during these interruptions the whole water ran into the gulf of Guiney.

"This opposition of currents suggested the idea of a machine, which, being sunk as far as the inferior current, and presenting a great surface, might force my vessel against the superior current, I made the experiment in miniature upon a boat; and I proceeded so far as to produce an equilibrium between the force of the superior current, joined to that of the wind, upon the boat, and the force of the inferior current upon the machine. I had not an opportunity of making trials on a larger scale. What I have related, sir, is a truth which may be confirmed by every navigator who has visited these climates.

"I imagine that the winds, as well as the rivers, which discharge themselves into the sea along this coast, and carry great quantities of earth into the gulf of Guiney, are the principal

causes of these effects. Besides, the bottom of this gulf, which, by its declivity, obliges the tide to run retrograde whenever it arrives at a certain level, and is incessantly pressed by fresh quantities, while the wind acts in a contrary direction upon the surface, and constrains part of the water to observe its ordinary course. This seems to be the more probable, because the sea enters from all quarters into this gulf, and issues only by revolutions which seldom happen. The moon has no apparent effect; for the same thing takes place during all its phases.

" I had occasion to be still farther convinced that the pressure of the water, when it comes to its level, joined to the inclination of the bottom, are the sole causes of this phænomenon. I found, that these currents exist only in proportion to the smaller or greater declivity of the shores; and I have every reason to believe, that they are not perceived beyond twelve or fifteen leagues from land, which is the greatest distance along the coast of Angola, where we can be certain of finding the bottom......

" The following circumstances seem to prove, that similar changes in the currents take place in the open sea. I made one of my experiments at a mean depth, namely, thirty-five fathoms. I found, at the depth of six or seven fathoms, that the course of the water ran north north-west. On sinking two or three fathoms more, my line stretched to the west north-west. At three or four fathoms deeper, the course was west south-

twenty-five and twenty-six fathoms, the course was south south-east, and towards the bottom it was south-east and east south-east. From these experiments I drew the following conclusions: that I might compare the ocean between Africa and America to a great river, the course of which is almost constantly directed to the north-west; that, as it runs along, it carries down sand and mud, which it deposits on its banks. These banks are, of course, heightened, and necessarily raise the level of the water, and oblige it to run retrograde in proportion to the declivity of the shore. But, as the water is direoted by a primitive impulse, it cannot return in a straight line: obeying the original movement, and yielding reluctantly to the last obstacle, it must necessarily describe a curve of greater or smaller extent, till it meets the middle current, with which it may partly unite, or which may serve it as a fulcrum, and give it a direction contrary to that impressed on it by the bottom. As the mass of water is in perpetual motion, the water towards the bottom, being nearer the cause and more pressed, must always undergo the first changes, and run in a direction contrary to the superior current, while the same cause reaches not different heights. These, sir, are my ideas. I have frequently taken advantage of these inferior currents; by sinking a machine to different depths, according to the number of fathoms water I happened to be in, I was enabled to sail against the upper current. I found, that, in calm water, and with a surface three times larger than that part of the prow

which is below the water, we could run from a third to half a league in the hour. Of this fact I was ascertained by my latitude, by boats which I anchored, and from which I found myself at a great distance an hour afterward; and, lastly, by the distance of certain points along the coasts."

These observations of M. Deslandes seem to be decisive, and I accede to them with pleasure. I cannot sufficiently thank him for demonstrating not only that my ideas on this subject were, in general, just, but that, in particular circumstances, they were liable to exceptions. It is not less certain, however, that the ocean forced open the Strait of Gibraltar, and, consequently, that the Mediterranean Sea received a great augmentation by this irruption. I rested this opinion not only on the current of the ocean into the Mediterranean, but on the situation of the land and the correspondence of the strata on the opposite coasts, which has often been remarked by intelligent navigators. "The irruption which formed the Mediterranean is evident, as well as that of the Black Sea by the strait of the Dardanelles, where the current is always violent, and the correspondence of the angles of the two coasts strongly marked, as well as the similarity of the strata, which are precisely the same on the opposite sides*."

Besides, the idea of M. Deslandes, who considers the sea between Africa and America as a grear river, the course of which is toward the

north-west, agrees perfectly with what I advanced concerning the water's running in greater quantity from the south than from the north pole.

Let us now briefly run over the coasts of the New Continent. We shall begin with Cape Hold-with-hope, which is situated in the seventy-third degree of north latitude. This is the most northerly point of land in New Greenland, and is distant from Cape North in Lapland about 160 or 180 leagues. From this cape the coast of Greenland might be traced to the polar circle, where the ocean forms a large strait between Iceland and Greenland. Some maintain, that this country in the neighbourhood of Iceland is not the Ancient Greenland, formerly possessed by the Danes as a dependent province. Its inhabitants were civilized Christians, who had bishops, churches, and a number of towns, proportioned to their trade. The Danes had a communication with them as easy, and as frequent, as the Spaniards with the Canary islands: there still exists, it is said, laws and regulations with regard to the government of this province, and these not of a very ancient date. However, without forming any conjectures how this country came to be absolutely lost, we find not in New Greenland the least vestige of what is here related. They are mere savages: they have no buildings: there is not a word in their language that has the smallest affinity to the Danish tongue; and there is not a single circumstance from which we can infer it to be the

same country. It is even almost a desert, and is covered with snow and ice the greatest part of the year. But, as these lands are of vast extent, and, as the coasts have been little frequented by modern navigators, they may have missed the place occupied by the descendants of these polished people; or the increase of the ice in this sea may now, perhaps, prevent all access to them. If, however, maps can be trusted, the whole coast of this country is known: it forms a large peninsula, at the extremity of which are the two straits of Frobisher and of Friesland, where the cold is excessive, although they are not farther north than the Orkneys, that is about sixty degrees.

Between the west coast of Greenland, and that of Labrador, the ocean forms a gulf, and then a large mediterranean, which is the coldest of all seas, and its coasts are little known. In pursuing this gulf, we meet with Davis's Strait, which leads to the Christian Sea, which last terminates in Baffin's Bay, through which there appears to be an outlet into Hudson's Bay. The strait of Cumberland, which, like that of Davis, may lead into the Christian Sea, is more narrow, and more subject to be frozen. Hudson's Strait, though much farther south, is also frozen for some part of the year: and it is remarkable, that the tides are very high in those seas and straits, although no tides take place in the inland seas of Europe, as the Baltic and Mediterranean. This difference seems to be occasioned by the motion of the sea from east to west, which pro-

duces high tides in straits opposite to the current of the waters, or whose mouths open to the east. But, in those of Europe, which open to the west, there are no tides. The ocean, by its general movement, rushes into the former, but flies from the latter; and this is the reason why the tides are so violent in the seas of China, Corea, and Kamtschatka.

In sailing down Hudson's Bay towards Labrador, there is a narrow opening, thirty leagues of which Davis traversed in 1586, and traded with the inhabitants. But no attempts have hitherto been made to discover the whole of this arm of the sea. We know nothing of the neighbouring country, but the land of the Esquimaux. Fort Pon-chartrin is the only settlement, and the most northerly part of this country; and it is separated from the island of Newfoundland by the small strait of Belleisle, which is little frequented. As the eastern coast of Newfoundland has the same direction with that of Labrador, this island appears to have been formerly a part of the continent, in the same manner as Isle-royal seems to have been detached from Acadia. The bottoms of the great bank, and of the lesser banks, on which the cod-fishery is carried on, are not deep; but, as they shelve a great way under water, they produce violent currents. Between Cape Breton and Newfoundland, there is a pretty large strait, which is the mouth of a small mediterranean called the *Gulf of St. Lawrence.* It sends off a branch, which extends a considerable way into

the country, and appears to be only the mouth of the river of that name. In this arm of the sea the tides are very perceptible; and even at Quebec, which is farther up the country, the waters rise several feet. Leaving the gulf of St. Lawrence, and following the coast of Acadia, we meet with a small gulf called *Boston Bay*, which is of a square figure, and advances a little way only into the land. But, before we pursue this coast any farther, it is worthy of remark, that, from Newfoundland to Guiana, the ocean forms an immense bay, that runs in upon the land as far as Florida, which is more than 500 leagues. This bay is similar to that of the Old Continent above described, where the ocean, after forming a large gulf between Kamtschatka and New Britain, gives rise to a great mediterranean, which comprehends the sea of Kamtschatka, of Corea, of China, &c. In the same manner, in the New Continent, the ocean, after forming a large gulf between Newfoundland and Guiana, gives rise to a great mediterranean, extending from the Antilles to Mexico; which confirms what we have advanced concerning the motion of the sea from east to west: for it appears that the ocean has gained as much territory on the east coast of America as on the east coast of Asia. Besides, these great gulfs in each continent lie under the same degrees of latitude, and are nearly of equal extent.' Such singular relations, it would appear, must have been produced by the same cause.

On viewing the islands and gulfs, which are

very numerous round Greenland, it is difficult, as navigators remark, not to suspect that the sea falls back from the poles towards the equator. What favours this conjecture is, that the tide rises eighteen feet at Cape des Etats, and only eight feet in the bay of Disko, *i. e.* at ten degrees of higher latitude*.

This observation, joined to that of the preceding article, seems still farther to confirm the movement of the waters of the ocean from the southern to the northern regions, where they are forced, by the resistance of the lands, to régorge or flow back toward the south.

In Hudson's Bay, vessels have to preserve themselves from mountains of ice, which are said to be from 1,500 to 1,800 feet thick, and which, being formed by a succession of long winters, in small gulfs perpetually filled with snow, have been detached by the north-west winds, or by some other powerful cause.

The north-west wind, which prevails perpetually during winter, and often in summer, excites, in the same bay, dreadful tempests. These are still more to be apprehended, because shoals are here very frequent. In the countries which bound this bay, the sun never rises nor sets without a great cone of light. When this phænomenon disappears, it is succeeded by the aurora borealis. Here the heavens are seldom serene. In spring and autumn the air is generally replete with thick fogs; and, during

* Hist. Gen. des Voyages, tom. xix. p. 2.

winter, with an infinity of small threads of ice, which are visible to the eye. Though the summer heats are considerable during two months or six weeks, thunder and lightning are rare *.

The sea along the coasts of Norway, which are bordered with rocks, is commonly from 100 to 400 fathoms deep, and the water is less salt than in warmer climates. The number of oily fishes with which this sea is filled, renders it so fat, that it is almost inflammable. The tide is here inconsiderable, the highest not rising above eight feet †.

Some observations have lately been made upon the temperature of the land and water in the climates adjacent to the north pole.

" In Greenland, the cold begins with the new year, and becomes so piercing in the months of February and March, that the stones split, and the sea smokes like a furnace, especially in the bays. In the midst of this thick fog, however, the frost is not so intense, as when the sky is unclouded: for, when we pass from the land to that foggy atmosphere which covers the surface and margins of the waters, we feel a milder air, though our hair and clothes are stiffened with hoar-frost. This fog produces more chilblains than a dry cold; and, when it

* Hist. Phil. et Polit. tom. vi. p. 308, 309.

†. Pontoppidan's Nat. Hist. of Norway; Journal Etranger, Aoât, 1755.

passes from the sea to a colder atmosphere, it instantly freezes, is dispersed through the horizon by the wind, and produces a cold so intense, that no person can go into the open air without running the hazard of having his hands and feet entirely frozen. It is in this season, that we see the water freeze on the fire before it boils. It is then that the winter paves a road of ice between islands, and in the bays and straits.

"Autumn is the finest season in Greenland. But its duration is short, and frequently interrupted by cold frosty nights. It is also about this time, that, in an atmosphere darkened with vapours, we see fogs which freeze and form a tissue on the sea similar to cobwebs; and, in the fields, the air is impregnated with lucid atoms, or sharp icicles like small needles.

"It has often been remarked, that the seasons in Greenland assume a temperature opposite to that which prevails in the rest of Europe. When the winter is rigorous in the temperate climates, it is mild in Greenland, and very severe in this northern region, when it is moderate in our countries. At the end of the year 1739, the winter was so mild in the bay of Disko, that the geese, in the month of January, passed from the temperate to the frozen zone in quest of warmer air; and that, in 1740, no ice was seen at Disko in the month of March; while, in Europe, the ice prevailed, without interruption, from October to May. . . . . .

"In winter 1763, which was extremely cold

over all Europe, the cold was so little felt in Greenland, that some summers have been less mild*."

We are assured by voyagers, that, in the seas adjacent to Greenland, there are very high mountains of floating ice, and others which resemble rafts of 200 fathoms in length, by sixty or eighty in breadth. But these boards of ice, which form immense plains upon the sea, are seldom above nine or twelve feet thick. They seem to be formed immediately on the surface when the cold is greatest. But the floating and very high masses come from the land, *i. e.* from the environs of mountains and coasts, from which they have been detached and carried down to the sea by the rivers. These masses of ice bring along with them great quantities of wood, which are afterwards thrown by the sea upon the eastern coasts of Greenland. This wood, it appears, neither comes from Labrador nor Norway; because the north-east winds, which are very violent in these countries, would push back the trees; and the currents which run to the south of Davis's Strait, and Hudson's Bay, would stop all that might come from America to the coasts of Greenland.

The sea begins to carry masses of ice to Spitzbergen in the months of April and May. A great number come from Davis's Strait, part of them from Nova Zembla, and the greatest num-

* Hist. Gen. des Voyages, tom. xix. p. 20, &c.

ber from the east coast of Greenland, being transported from east to west according to the general movement of the ocean.

The following facts and notices are to be found in the voyage of captain Phipps: "The idea of a passage to the East Indies by the north pole was suggested as early as the year 1527, by Robert Thorne, merchant of Bristol. . . . . . ." No voyage, however, appears to have been undertaken to explore the circumpolar seas, till the year 1607, when "Henry Hudson was set forth, at the charge of certain worshipful merchants of London, to discover a passage by the north pole to Japan and China. . . . And this I can assure at this present, that between seventy-eight degrees and a half, and eighty-two degrees, by this way there is no passage.

"In 1609, a voyage was set forth by the right worshipful sir Thomas Smith to the south part of Spitzbergen; and, when near Foreland, he sent his mate ashore; and speaking of the account he gave at his return, says, Moreover, I was certified that all the ponds and lakes were unfrozen, they being fresh water; which putteth me in hope of a mild summer here, after so sharp a beginning as I have had; and my opinion is such, and I assure myself it is so, that a passage may be as soon attained this way by the pole, as any unknown way whatsoever, by reason the sun doth give a great heat in this climate, and the ice (I mean that freezeth here)

is nothing so huge as I have seen in seventy-three degrees . . . . Several other voyagers have attempted to discover this passage, but without success."

On the 5th of July, captain Phipps saw great quantities of floating ice about the 79° 34′ of latitude. The weather was foggy. The next day he continued his course as far as the 79° 59′ 39″ between Spitzbergen and the ice. On the 7th, he proceeded through the floating masses of ice in quest of an open passage to the north, by which he might gain an open sea. But the ice to the north north-west formed one continued mass; and at 80° 36′ the sea was entirely frozen; so that all the attempts of captain Phipps to discover a passage proved abortive. "On the 12th of September, Dr. Irvine tried the temperature of the sea in a state of great agitation, and found it considerably warmer than that of the atmosphere. This observation is the more interesting, as it agrees with a passage in Plutarch's Natural Questions, not (I believe) before taken notice of, or confirmed by experiment, in which he remarks, 'that the sea becomes warmer by being agitated in waves. . . .' These gales are as common in the spring as in the autumn: there is every reason to suppose, therefore, that at an early season we should have met with the same bad weather in going out as we did on our return." And, as captain Phipps departed from England in the end of May, he certainly took the season most favourable to his expedition. . . . . . "There was

bability, if ever navigation should be practicable to the pole, of finding the sea open to the northward after the solstice; the sun having then exerted the full influence of his rays, though there was enough of the summer still remaining for the purpose of exploring the seas to the northward and westward of Spitzbergen."

I agree entirely with this able navigator; and I suspect that the expedition to the pole cannot be renewed with success, and that we can never reach beyond the eighty-second or eighty-third degree. We are assured that a vessel from Whitby, in the year 1774, penetrated as far as the eightieth degree, without seeing ice sufficient to prevent sailing still farther. A captain Robinson is likewise quoted, from whose journal it appears that, in 1773, he arrived at the 81° 30′. Lastly, a Dutch ship of war, sent to protect the whale-fishers, is said to have advanced, about fifty years ago, as far as the eighty-eighth degree. Dr. Campbell, it is added, received this intelligence from a Dr. Dallie, who was in the vessel, and practised physic in London in the year 1745*. This is probably the same navigator whom I formerly quoted under the name of captain Mouton. But I am extremely suspicious of the fact; and I am persuaded, that we shall in vain attempt to reach beyond the eighty-second or eighty-third degree; and that, if a passage by the north is practicable, it can only be by the way of Hudson's Bay.

* Gazette de Literature, Août 9, 1774, No. 61.

On this subject, the following passage of the learned and ingenious author of the History of the Two Indies merits attention: "Hudson's Bay always has been, and is still looked upon as the nearest road from Europe to the East Indies, and to the richest parts of Asia.

"Cabot was the first who entertained an idea of a north-west passage to the South Seas; but his discoveries ended at Newfoundland. After him followed a crowd of English navigators, many of whom had the honour of giving their names to savage coasts which no mortal had ever visited before. These bold and memorable expeditions were more striking than really useful. The most fortunate of them did not furnish a single idea relative to the object of pursuit. The Dutch, less frequent in their attempts, and who pursued them with less ardour, were of course not more successful, and the whole began to be treated as a chimera, when the discovery of Hudson's Bay rekindled all the hopes that were nearly extinguished.

"From this time the attempts were renewed with fresh ardour. Those that had been made before in vain by the mother country, whose attention was engrossed by her own intestine commotions, were pursued by New England, whose situation was favourable to the enterprise. Still, however, for some time, there were more voyages undertaken than discoveries made. The nation was a long time kept in suspense by the contradictory accounts received from the adventurers. While some maintained the possibility,

some the probability, and others asserted the certainty of the passage; the accounts they gave, instead of clearing up the point, involved it in still greater darkness. Indeed these accounts are so full of obscurity and confusion, they are silent upon so many important circumstances, and they display such visible marks of ignorance and want of veracity, that, however impatient we may be of determining the question, it is impossible to build any thing like a solid judgment upon testimonies so suspicious. At length, the famous expedition of 1746 threw some kind of light upon a point which had remained enveloped in darkness for two centuries past. But upon what grounds have the latter navigators entertained better hopes? What are the experiments on which they found their conjectures?

"Let us proceed to give an account of their arguments. There are three facts in natural history, which henceforward must be taken for granted. The first is, that the tides come from the ocean, and that they extend more or less into the other seas, in proportion as their channels communicate with the great reservoir by larger or smaller openings; from whence it follows, that this periodical motion is scarcely perceptible in the Mediterranean, in the Baltic, and other gulfs of the same nature. A second matter of fact is, that the tides are much later and much weaker in places more remote from the ocean, than in those which are nearer to it. The third fact is, that violent winds, which blow in a direction with the tides, make them rise above their ordinary

boundaries, and that those which blow in a contrary direction retard their motion, at the same time that they diminish their swell.

" From these principles, it is most certain that, if Hudson's Bay were no more than a gulf inclosed between two continents, and had no communication but with the Atlantic, the tides in it would be very inconsiderable; they would be weaker in proportion as they were farther removed from the source, and would be less strong wherever they ran in a contrary direction to the wind. But it is proved, by observations made with the greatest skill and precision, that the tides are very high throughout the whole bay. It is certain that they are higher towards the bottom of the bay than even in the strait itself, or at least in the neighbourhood of it. It is proved that even this height increases whenever the wind blows from a corner opposite to the strait: it is, therefore, certain, that Hudson's Bay has a communication with the ocean, beside that which has been already found out.

" Those who have endeavoured to explain these very striking facts, by supposing a communication of Hudson's with Baffin's Bay, or with Davis's Straits, are evidently mistaken. They would not scruple to reject this opinion, for which indeed there is no real foundation, if they only considered that the tides are much lower in Davis's Straits, and in Baffin's Bay, than in Hudson's.

" But if the tides in Hudson's Bay can come

other northern sea, in which they are constantly much weaker, it follows that they must have their origin in the South Sea. And this is still farther apparent from another leading fact, which is, that the highest tides ever observed upon these coasts, are always occasioned by the north-west winds, which blow directly against the mouth of the strait.

"Having thus determined, as much as the nature of the subject will permit, the existence of this passage, so long and so vainly wished for, the next point is to find out in what part of the bay it is to be expected. From considering every circumstance, we are induced to think, that the attempts, which have been hitherto made without either choice or method, ought to be directed towards Welcome Bay, on the western coast. First, the bottom of the sea is to be seen there at the depth of about eleven fathoms, which is an evident sign that the water comes from some ocean, as such a transparency could not exist in waters discharged from rivers, or in melted snow or rain. Secondly, the currents keep this place always free from ice, while all the rest of the bay is covered with it; and their violence cannot be accounted for but by supposing them to come from some western sea. Lastly, the whales, who towards the latter end of autumn always go in search of the warmest climates, are found in great abundance in these parts towards the end of summer, which would seem to indicate that there is an outlet for them from thence to the south seas, not to the northern ocean.

"It is probable that the passage is very short. All the rivers that empty themselves on the western coast of Hudson's Bay are small and slow, which seems to prove that they do not come from any distance; and that, consequently, the lands which separate the two seas are of a small extent. This argument is strengthened by the height and regularity of the tides. Wherever there is no other difference between the times of the ebb and flow, but that which is occasioned by the retarded progression of the moon in her return to the meridian, it is a certain sign that the ocean from whence those tides come is very near. If the passage is short, and not very far to the north, as every thing seems to promise, we may also presume that it is not very difficult. The rapidity of the currents observable in these latitudes, which prevents any flakes of ice from continuing there, cannot but give some weight to this conjecture."

I believe, with this excellent writer, that if a practicable passage exists, it must be at the bottom of Hudson's Bay, and that all attempts by Baffin's Bay will be fruitless, because the climate is too cold, and its coasts are always frozen, especially towards the north. But the existence of this passage is rendered still more doubtful by the lands discovered, in 1741, by Bering and Tchirikow, under the same latitude with Hudson's Bay; for these lands seem to form a part of the great continent of America, which appears to stretch under the same latitude as far as the polar circle.

only be found about the fifty-fifth degree of north latitude.

If we examine the position of the Antilles, beginning with the island of Trinidad, which is the southmost, it is impossible to doubt but that Trinidad, Tobago, the Granades, St. Vincent, Martinico, Marygalante, Antigua, Barbadoes, and all the adjacent isles, once formed a chain of mountains, which extended from south to north, like Newfoundland and the country of the Esquimaux. Farther, the direction of the Antilles from east to west, if we begin with Barbadoes, and pass on to St. Bartholomy, Porto-Rico, St. Domingo, and Cuba, is nearly the same with the coasts of Cape Breton, Acadia, and New England. All these islands lie so contiguous, that they may be regarded as a continued belt of land, and as the most elevated parts of a country now occupied by the sea. Most of them are nothing but the tops of mountains; and the sea between them and the continent is a true mediterranean, in which the tides are not much more perceptible than in our Mediterranean, although the straits between the islands are directly opposed to the motion of the sea from east to west, which should contribute to raise the tides in the gulf of Mexico. But, as this gulf is very broad, the waters elevated by the tide when expanded over a large surface, hardly produce any sensible change upon the coast of Louisiana and several other places.

Both the Old and New Continents, therefore, appear to have been encroached upon by the

ocean in the same latitudes: both are furnished with a great mediterranean, and a vast number of islands, which likewise lie nearly in the same latitudes. The only difference is, that the Old Continent being much larger than the New, has a mediterranean on its west coast, to which the New Continent has nothing analogous. But both seem to have undergone similar revolutions. These revolutions are greatest near their middle parts, or between the tropics, where the motion of the sea is most violent.

The coasts of Guiana, from the mouth of the river Oronoko to that of the Amazons, exhibit nothing remarkable. But the Amazons, which is the largest river in the universe, forms a considerable sheet of water near Coropa, before it discharges itself into the sea by the two mouths which surround the island of Caviana. From the mouth of the Amazons to Cape St. Roche, the river runs almost straight east; from Cape St. Roche to Cape St. Augustine it runs south, and from Cape St. Augustine to the bay of All Saints, it runs westward in such a manner that this part of Brasil projects considerably into the ocean, which is directly opposite to a similar projection of the African coast. The bay of All Saints is a small arm of the sea, which advances about fifty leagues into the land, and is much frequented by navigators. From this bay to Cape St. Thomas, the coast runs straight south, and from thence, in a south-west direction, to the mouth of the Plata, where an arm of the sea

this river, to the southern extremity of America, the ocean forms a large bay, which is terminated by Falkland Island, Cape Assumption, and other lands bordering on Terra del Fuego. At the bottom of this bay is the strait of Magellan, the longest in the universe, and where the tides rise very high. Beyond this is the strait of La Maire, which is much shorter; and, lastly, Cape Horn, which is the south point of America.

On the subject of points or head-lands, it is remarkable, that they all regard the south, and that most of them are cut by straits which run from east to west. The point of South America regards the arctic pole, and it is cut by the strait of Magellan: that of Greenland, which likewise has a southern aspect, is cut from east to west by the strait of Frobisher: that of Africa regards also the south, and, beyond the Cape of Good Hope, are banks and shoals which appear to have been separated from it: that of the peninsula of India is cut by the strait between it and the island of Ceylon; and, like all others, projects southward. These are facts; but we are unable to give any explication of them.

From Terra del Fuego, all along the west coast of South America, the ocean makes considerable advances into the land; and this coast seems to follow exactly the direction of the high mountains which traverse this part of the continent from south to north, from the equator to the arctic pole. Near the line, the ocean forms a large bay, extending from Cape St. Francois to Panama, that famous isthmus, which, like that

of Suez, prevents the junction of the two seas. If these two necks of land were removed, both the Old and the New Continent would be divided into two distinct portions. From Panama to California, there occurs nothing worthy of remark. Between the peninsula of California and New Mexico, is a long arm of the ocean, called the Vermilion Sea, which is more than 200 leagues long. In fine, the west coast of California has been traced to the forty-third degree of latitude. It was in this latitude that Drake, who first discovered the land to the north of California, and which he called New Albion, was obliged, by the rigour of the cold, to change his course, and to anchor in a small bay which bears his name; so that the countries beyond the forty-third or forty-fourth degree, in this part of the globe, are as little known as those of North America, beyond the forty-eighth degree, which is inhabited by the Moozemleki, and the fifty-first, which is inhabited by the Assiniboils. The territory of the former savages extends much farther west than that of the latter. All beyond, for 1,000 leagues in length, and as much in breadth, is totally unknown, unless the Russians, as they pretend, have made some discoveries by departing from Kamtschatka, and visiting the eastern coasts of North America.

The ocean, then, surrounds the whole globe, without interruption, and we may sail round it by taking our departure from the south point of America. But we are still uncertain whether the ocean surrounds, in the same manner, the

north part of the globe; and all the navigators, who have attempted to go from Europe to China by the north-east or north-west, have equally failed in their enterprises.

Lakes differ from mediterraneans; the former derive no water from the ocean; on the contrary, when they communicate with seas, they are constantly discharging water into them. Thus the Black Sea, which some geographers have regarded as a branch of the Mediterranean, and, of course, as an appendage of the ocean, is only a lake; because, in place of receiving any supplies from the Mediterranean, its waters run with rapidity through the Bosphorus into the lake called the sea of Marmora, and from thence through the straits of the Dardanelles into the Grecian Sea. The Black Sea is about 250 leagues long, and 100 broad: it receives a number of large rivers, as the Danube, the Nieper, the Don, the Bog, the Donjec, &c. The Don, which unites with the Donjec, before it arrives at the Black Sea, forms a lake called the *Palus Meotis,* which is more than 100 leagues in length, and from twenty to twenty-five in breadth. The sea of Marmora, which is below the Black Sea, is a lake smaller than the Palus Meotis, being not above fifty leagues long, and eight or nine broad.

It is related by some of the ancients, and particularly by Diodorus Siculus, that the Euxine, or Black Sea, was originally a great river or lake, and had no communication with the Greek Sea; but that its waters were, in the course of

time, so greatly augmented by the rivers which fall into it, that they forced a passage, first by the islands of Cyanea, and then by the Hellespont. This opinion has great probability on its side; and, I think, it is no difficult matter to explain how the operation was effected: for, supposing the bottom of the Black Sea to have been formerly much lower than it is now, the mud and sand carried down by the rivers would gradually raise it, till the surface of the water was elevated above that of the land, and then the water would necessarily find a passage for itself: and, as the rivers continue still to transport sand and earth, and as, at the same time, the quantity of water in the rivers diminishes in proportion as the mountains from which they spring are lowered, it may happen, in the course of ages, that the Bosphorus will again be filled up. But, as effects of this nature depend on many causes, we must content ourselves with simple conjectures. M. Tournefort, on the authority of the ancients, says, that the Black Sea, which receives the waters of a great part of Europe and Asia, after being considerably augmented, opened to itself a passage by the Bosphorus, and either formed the Mediterranean, or increased its waters to such a degree, that that they forced a passage to the ocean through the Straits of Gibraltar; and that the island of Atalantis, mentioned by Plato, was on this occasion totally overflowed. This notion cannot be supported; for the ocean runs into the Mediterranean, and not the Mediterranean into the

ocean. Besides, M. Tournefort has not combined two essential facts, though he has mentioned both of them. The first is, that the Black Sea receives nine or ten rivers, each of which furnishes more water than is discharged by the Bosphorus; and the second, that the Mediterranean does not receive more water from rivers than the Black Sea, though it be seven or eight times larger; and what it receives from the Bosphorus is not the tenth part of what falls into the Black Sea. How, therefore, could this tenth part of the water, that falls into a small sea, produce not only a larger sea, but augment its waters to such a degree as would enable it to break down the isthmus of Gibraltar, and overwhelm an island of greater extent than the whole of Europe? It is easy to perceive that M. Tournefort has not sufficiently considered this matter. The Mediterranean derives from the ocean at least ten times the quantity of water it receives from the Black Sea; for the narrowest part of the Bosphorus exceeds not 800 paces, while that of the Straits of Gibraltar is more than 5,000; and supposing the velocities of both to be equal, still the water in the Straits of Gibraltar is by much the deepest.

M. Tournefort, who ridicules Polybius for predicting that the Bosphorus will in time be filled up, has not attended sufficiently to circumstances, otherwise he would not have pronounced the impossibility of such an event. Must not the Black Sea, which constantly receives the sand and mud of eight or ten large rivers, gra-

dually fill up? Must not the winds and the natural current of the waters continually transport part of these matters into the Bosphorus? It is, therefore, extremely probable, that, in the course of ages, the Bosphorus will be choked up, when the quantity of water discharged by the rivers into the Black Sea shall be greatly diminished. Now, the rivers are diminishing daily, because the mountains, which collect the dews, and give rise to the rivers, are continually decreasing.

The Black Sea receives more water from rivers than the Mediterranean; and M. Tournefort observes, on this subject, "That the greatest rivers in Europe fall into this sea by means of the Danube, into which are discharged the rivers of Suabia, Franconia, Bavaria, Austria, Hungary, Moravia, Corinthia, Croathia, Bothnia, Servia, Transylvania, and Wallachia: the rivers of Black Russia and of Podolia fall likewise into the same sea by means of the Niester; those of the southern and eastern parts of Poland, of the northern part of Muscovy, and of the country of the Cossacks, fall into it, either by the Nieper or Boristhenes; the Tanais and the Copa empty themselves into the Black Sea by the Cimmerian Bosphorus; the rivers of Mingrelia, the principal of which is the Phasis, also discharge their contents into this sea, and likewise the Casalmac, the Sangaris, and other rivers of Asia Minor which take a northern course: but the discharge through the Thracian Bosphorus, which is the only outlet from

the Black Sea, is not comparable to that of any one of these great rivers *."

All these facts demonstrate the great quantity of water carried off by evaporation; and it is owing to this circumstance that the ocean constantly runs into the Mediterranean by the Straits of Gibraltar. It is difficult to ascertain the quantity of water received by any sea; it requires an exact knowledge of the breadth, depth, and velocity of all the rivers that fall into it, of their augmentation and diminution in different seasons of the year, and of the quantity which the sea loses by evaporation. This last is the most difficult to determine; for supposing evaporation to be proportioned to the surfaces, it will be greater in a warm than in a cold climate. Besides, water mixed with salt and bitumen evaporates more slowly than fresh water; a sea subject to great agitation evaporates more quickly than a calm sea; and a difference in the depth has also some effect. In fine, so many particulars are included in the theory of evaporation, that it is not possible to make an exact estimation of its quantity.

The water of the Black Sea is less clear and less salt than that of the ocean. There are no islands in it; and its tempests are more violent and more dangerous than those of the ocean; because its waters, being extended in a basin which has but an inconsiderable outlet, move,

* See Voyage du Levant de Tournefort, vol. ii. p. 123.

when agitated, in whirlpools, which beat upon all sides of a vessel with an insupportable violence*.

After the Black Sea, the greatest lake in the world is the Caspian Sea, which extends from south to north about 300 leagues, and its mean breadth exceeds not fifty. This lake receives the Wolga, besides several other considerable rivers, as the Kur, the Faie, and the Gempo. But, what is singular, it receives not one river from the east coast; the country on that side is a sandy desert, which remained, till lately, altogether unknown. The Czar Peter I. sent engineers to make a chart of the Caspian Sea. It had been represented as round by former geographers; but it is very long and very narrow. Its eastern coast, and the neighbouring country, were entirely unknown; even Lake Aral, which is about 100 leagues east of the Caspian, was either not known to exist, or was considered as a part of this sea. Thus, before the discoveries of the Czar, there was in this region an unknown country of 300 leagues in length, and 100 or 150 in breadth. Lake Aral is nearly oblong, and about ninety or 100 leagues long, and fifty or sixty broad. It receives the Sideroias and the Oxus, two large rivers; but, like the Caspian, it has no outlet for discharging its waters; and, as the Caspian receives no rivers from the east, Lake Aral, on the contrary, receives none

* See Voyages de Chardin, p. 142.

from the west. Hence, it is presumable, that these two formerly constituted but one lake; and the rivers being gradually choked up, the country between them would necessarily be covered with sand. There are some small islands in the Caspian; and its waters are much fresher than those of the ocean. Storms, in this sea, are exceedingly dangerous; and it affords not navigation to large vessels, on account of shoals, sand-banks, and rocks concealed under the surface. "The largest vessels employed on the Caspian," says Pietro della Valle*, "along the coasts of the province of Mazanda in Persia, where stands the town of Ferhabad, although they be called *ships*, are no better than our tartanes: their sides are high; they draw little water, and are flat bottomed. They are built of this construction, not only because the sea is shallow near the coasts, but because it is full of shoals and sand-banks; so that no other vessels could be used with safety. I was surprised to see no fishing carried on at Ferhabad, except salmons at the mouth of the river, a bad kind of sturgeon, and other fresh water fishes of no value. I attributed this to their ignorance of navigation and of the art of fishing, till I was informed by the Cham of Esterabad, that this sea, at the distance of twenty or thirty miles from the shore, is so shallow, that nets could not be used with advantage; and that the same rea-

* Tom. iii. p. 235.

son accounted for the construction of their vessels, which carry no cannon, because the Caspian is not infested with pirates."

Struys, Avril, and others, affirm, that, in the neighbourhood of Kilan, there are two gulfs, which swallow up the waters of the Caspian, and carry them, by subterraneous passages, into the Persic Gulf. De Fer, and other geographers, have laid down these gulfs in their maps, though we are assured by the Czar's envoys, that they have no existence*. The fact, with regard to the willow leaves found on the Persic Gulf, and which are alleged by the same authors to be transported from the Caspian Sea, because no willows grow near the Persic Gulf, appears to be equally improbable, as the subterraneous passages which Gemelli Careri, as well as the Russians, maintain to be altogether imaginary. Besides, the Caspian is about a third less than the Black Sea, which last also receives more water by rivers; evaporation, therefore, is alone sufficient to carry off all its adventitious waters, without the assistance of imaginary gulfs or subterraneous passages.

To what was advanced in order to prove, that the Caspian Sea is only a lake, and never had any communication with the ocean, I have to add the answers I received from the Academy of Petersburg to some queries I transmitted them concerning this sea.

" Augusto 1748, October 5, &c. Cancellaria

* See Mem. de l' Acad. des Sciences, ann. 1721.

Academiæ Scientiarum mandavit, ut Astrachanensis Gubernii Cancellaria responderet ad sequentia. 1. Suntne vortices in mari Caspico necne? 2. Quæ genera piscium illud inhabitant? Quomodo appellantur, et an marini tantum aut et fluviatiles ibidem reperiantur? 3. Qualia genera concharum? Quæ species ostrearum et cancrorum occurrunt? 4. Quæ genera marinarum avium in ipso mari aut circa illud versantur? ad quæ Astrachensis Cancellaria d. 13. Mart. 1749, sequentibus respondit.

" Ad 1. in mari Caspico vortices occurrunt nusquam; hinc est quod nec in mappis marinis extant, nec ab ullo officialium rei navalis visi esse perhibentur.

" Ad 2. pisces Caspinum mare inhabitant; Acipenseres, Sturioli, Gmel, Siruli, Cyprini clavati, Bramæ, Percæ, Cyprini ventre acuto, ignoti alibi pisces, Tincæ, Salmones, qui, ut e mari fluvios intrare, ita et in mare e fluviis remeare solent;

" Ad 3. Conchæ in littoribus maris obviæ quidem sunt, sed parvæ, candidæ, aut ex unâ parte rubræ. Cancri ad littora observantur magnitudine fluviatilibus similes; Ostreæ autem et capita Medusæ visa sunt nusquam.

" Ad 4. aves marinæ quæ circa mare Caspium versantur sunt Anseres vulgares et rubri, Pelicani, Cygni, Anates rubræ et nigricantes, Aquilæ, Corvi aquatici, Grues, Plateæ, Ardeæ albæ, cinereæ, et nigricantes, Ciconiæ albæ gruibus similes, Karawaiki (ignotum avis nomen) larorum variæ species, Sturni nigri et lateribus

albis instar picarum, Physiani, Anseres parvi nigricantes, Tudaki (ignotum avis nomen) albo colore præditi."

These facts, which are both accurate and authentic, confirm my position, that the Caspian Sea has no subterraneous communication with the ocean. They prove farther, that this sea never formed a part of the ocean; for it contains neither oysters nor any other sea shells, but such species only as are found in rivers. We are, therefore, warranted to conclude, that this sea is nothing but a great lake formed by the waters of rivers, since we find in it the same fishes and the same shells which inhabit the rivers, and none of those which people the ocean or the Mediterranean.

There are lakes or seas, which neither receive nor discharge rivers; there are others which both receive and discharge, and others which only receive. The Caspian, Lake Aral, and the Dead Sea, are of the last kind: in Asia Minor, there is a small lake of the same species: there is another still larger in Persia, upon which the city of Marago is situated: it is of an oval figure, and about ten or twelve leagues long, and six or seven broad: it receives the Tauris, which is not a very considerable river. If to these we add a small lake of the same nature in Greece, twelve or fifteen leagues from Lepanto, we have an enumeration of all the known lakes in Asia which belong to this species. In Europe, there is not a single one of any consideration. There

are several small lakes of this kind in Africa, as those which receive the rivers Ghir, Zez, Touguedot, and Tasilet. These four lakes lie at no great distance from one another, and are situated on the frontiers of Barbary, near the desert of Zaara. There is another in the province of Kovar, which receives the river that runs through the country of Berdoa. In North America, which abounds with lakes, there are none of this kind, except two small collections of water formed by brooks, the one near Guatimapo, and the other some leagues from Realnuevo, both in Mexico. But in Peru there are two contiguous lakes, one of which, Lake Titicaca, is very large, and receives a river which rises near Cusco; but it gives rise to no river. There is a small lake in Tucuman, which receives the river Salta; another, in the same country, of greater extent, receives the Santiago; and three or four between Tucuman and Chili.

Those lakes, which neither receive nor give rise to any river, are more numerous than the kind just mentioned. They are a species of swamps, which collect the rain water; or, they may originate from subterraneous waters that issue in the form of springs in low grounds, from which there is no fall to carry them off. Those rivers that overflow may also leave stagnating waters upon the land, which remain a considerable time, and are occasionally recruited by subsequent inundations. Salt lakes may sometimes be produced by inundations from the

sea, as that at Harlem, and several others, in Holland, to which no other origin can be ascribed. The sea, likewise, by abandoning certain lands, may have left lakes in the low grounds of particular countries, and which continue to be maintained by the rains. Of this kind, there are small lakes in Europe, as in Ireland, in Jutland, in Italy, in the country of the Grisons, in Poland, in Muscovy, in Finland, and in Greece: but all these are of little consideration. In Asia, near the Euphrates, in the desert of Irac, there is one above fifteen leagues long; another in Persia, nearly of the same extent, upon which are situated the towns of Kelat, Tetuan, Vastan, and Van; a small one in Chorazan, near Ferrior; another in Independent Tartary, called Lake Levi; two in Muscovite Tartary; one in Cochinchina; and, in fine, a pretty large one not far from Nankin. This last, however, communicates with the neighbouring sea by a canal of considerable extent. In Africa, there is a small lake of this species in the kingdom of Morocco; another near Alexandria, which appears to have been left by the sea; another, eight or ten leagues long, formed by the rain water, in the desert of Azarad, about the thirtieth degree of latitude; another, still larger, upon which is situated the town of Gaoga, under the twenty-seventh degree; another, but much smaller, near the town of Kanum, under the thirtieth degree; one near the mouth of the river Gambia; several others in Congo, about the second or third degree of south latitude; two others in the country

of the Caffres; one of them, called Lake Rufumbo, is not very extensive; and the other, which lies in the province of Arbuta, is perhaps the largest of this kind, being about twenty-five leagues long, and seven or eight broad: there is likewise one of these lakes near the east coast of Madagascar, about the twenty-ninth degree of south latitude.

In America, there is one of these lakes situated in the middle of the peninsula of Florida, which has an island called Serrope in its centre. The lake near the town of Mexico, which is round, and about ten leagues in diameter, belongs likewise to this species. There is another still more extensive in New Spain, about twenty-five leagues from the eastern coast of the bay of Campeachy; and another, of smaller dimensions in the same country, near the coast of the South Sea. Some travellers have affirmed, that, in the interior parts of Guiana, there is a very large lake of this species, which they call Golden Lake, or Lake Parima; and they have given marvellous accounts of the riches of the neighbouring country, and of the great quantities of gold dust found in this lake, which they allege to be more than 400 leagues in length, and above 125 in breadth: no river, it is said, either enters into or issues from it. Though this lake be laid down in several maps, its existence is still problematical.

But the most common and the most extensive lakes are those which both receive and give rise to rivers: as they are exceedingly numerous, I

shall only mention the largest, or the most remarkable of them. Beginning with Europe, we have, in Switzerland, the lake of Geneva, that of Constance, &c. In Hungary, Lake Balaton, and another, of equal extent, in Livonia, which separates this province from Russia: Lake Lapwert in Finland, which is very long, and divides into several branches, and Lake Oula, which is of a circular figure: in Muscovy, Lake Ladoga, which is more than twenty-five leagues long, and above twelve broad; Lake Onega, which is equally long, but not so broad; Lake Ilmen; Lake Belozero, which is one of the sources of the Wolga; Lake Iwan-Osero, which is one of the sources of the Don; and two other lakes, from which the river Vitzogda derives its origin: in Lapland, the lake from which issues the river Kimi; another, much larger, and situated near the coast of Wardhus; and several others of less note, which give rise to the rivers Lula, Pitha, and Uma: in Norway, two lakes nearly of the same dimensions with those of Lapland: in Sweden, Lake Vener, which is as large as Lake Meller, upon which Stockholm is situated; and two less considerable, one near Elvedal, and the other near Lincopin.

In Siberia and in Muscovite and Independent Tartary, there are a great number of these lakes, of which the principal are, the great Lake Baraba, which is more than 100 leagues long, and the waters of which fall into the Irtis; the great Lake Estraguel, the source of the Irtis; several lesser ones, the sources of the Jenisca; the great

Lake Kita, the source of the Oby; another great lake, the source of the Angara; Lake Baical, which is more than seventy leagues long, and is formed by the river Angara; and Lake Pehu, the source of the Urack, &c. In China and Chinese Tartary, we have Lake Dalai, the source of the great river Argus, which falls into the Amour; the lake of the Three Mountains, the source of the river Helum, which falls likewise into the Amour; the lakes of Cinhal, Cokmor, and Sorama, the sources of the river Hoamho; two large lakes in the neighbourhood of Nankin, &c. In Tonquin is the Guadag, a lake of considerable magnitude. In India, we have Lake Chiamat, which is the source of the river Laquia, and lies near the sources of the Ava, the Longenu, &c. This lake is more than fifty leagues long, and about forty broad. The source of the Ganges is another lake; and one near Cashmire gives rise to the Indus, &c.

In Africa, there are Lake Cayar, and two or three others, near the mouth of the Senegal; Lake Guarda, and Lake Sigismus, which, together, make a triangular lake of 100 leagues long and 75 broad, and contain a considerable island. It is in this lake that the Niger loses its name, and, at its exit, assumes that of Senegal. In ascending towards the course of this river, we meet with another pretty large lake called Bournou, where the Niger again changes its name; for the river that falls into this lake is called Gombaru. At the sources of the Nile in Ethiopia, is the great Lake Gambia, which is above

fifty leagues long. On the coast of Guiney are also several lakes, which appear to have been originally formed by the sea; and there are few others in Africa of any note.

North America is the country of lakes. The most extensive of them are, Lake Superior, which is about 125 leagues long, and fifty broad; Lake Huron, which is near 100 leagues in length, and about forty in breadth; Lake Illionois, which, comprehending the bay of Puants, is nearly as extensive as Lake Huron; Lake Erie and Lake Ontario, which, together, exceed eighty leagues in length, by twenty or twenty-five in breadth; Lake Mistasin, to the north of Quebec, is about fifty leagues long: Lake Champlain, to the south of Quebec, is nearly of equal length; Lake Alemipigon, and Lake Christinaux, both to the north of Lake Superior, are likewise considerable; the lake of Assiniboils contains several islands, and is more than seventy-five leagues long: besides the Mexican Gulf, there are two considerable lakes in that country; that called Nicaragua, in the province of the same name, is about seventy leagues in length.

Lastly, in South America, there is a small lake, the source of the Maragnon. A more extensive one gives rise to the river Paraguay: there are, besides Lake Titicares, the waters of which fall into the river Plata; two lesser ones, which discharge their waters into the same river; and some inconsiderable ones in the interior parts of Chili.

All lakes that give rise to rivers, and all those

which occur in the course of rivers, or which border upon and discharge their waters into rivers, are not salt. Almost all those, on the contrary, which receive rivers, but give rise to none, are salt. This circumstance seems to favour the opinion, that the saltness of the sea is occasioned by salts brought down from the land by the rivers; for we find that salt does not evaporate; and, of course, all that is transported by the rivers remains in the sea: although the water of rivers appears to be fresh, it is well known, that it contains a small quantity of salt, which, in the course of ages, might accumulate to such a degree as would be sufficient to produce the present saltness of the sea, which must be continually augmenting. It is in this manner, I presume, that the Caspian, Lake Aral, and the Black Sea, have become salt. With regard to those seas, which, like marshes, or swamps, neither receive nor discharge rivers, they are either salt or fresh according to their origin. Those in the neighbourhood of the sea are commonly salt; and those at a distance from it are fresh; because the former have originated from inundations of the sea, and the latter from fresh fountains.

In the country of the Ufian Tartars, so called, because they inhabit the banks of the river Uf, there are, M. Pallas remarks, lakes, the waters of which were formerly fresh, and are now salt. He makes the same remark concerning a lake near Miacs.

One of the lakes most famous for the quan-

tity of salt extracted from it, is that near the banks of the river Isel, called Soratschya. The salt of it, in general, is bitter, and employed by the physicians as a good purgative. Two ounces of this salt make a very strong dose. Near Kurtenegsch, the shoals are covered with a bitter salt, which rises, like a field of snow, to the height of two inches. The lake Korjackof furnishes annually three hundred thousand cubic feet of salt *. Lake Jennu likewise furnishes a great quantity.

In the voyages performed under the auspices of the Academy of Petersburg, mention is made of the salt lake of Jamuscha in Siberia. This lake, which is nearly round, is only about nine leagues in circumference. Its margins are covered with salt, and the bottom is clothed with crystals of salt. The water is extremely salt; and, when the sun shines, it appears reddish, like the sky in a fine morning. The salt is as white as snow, and forms itself into cubic crystals. The quantity of it is so immense, that a number of vessels may, in a short time, be loaded with it; and, after it has been removed, it is again replaced in five or six days. It is sufficient to remark, that it supplies the provinces of Tobolski and Jeniseik, and that this lake could supply fifty provinces of similar extent. The commerce of this, as well as of all other salt, is reserved in the hands of the crown. This salt is exceedingly

* The cubic foot weighs thirty-five pounds, each of sixteen ounces.

good. It surpasses all others in whiteness, and none is more proper for curing meat. In the south of Asia, there are likewise salt lakes, one near the Euphrates, and another in the neighbourhood of Barra. There are others, it is said, near Haleb, and at Larneca in the island of Cyprus. This last borders upon the sea. The salt valley of Barra, being at no great distance from the Euphrates, might be worked, if its waters were made to run into this river, and if the earth was good: but at present this earth yields a good salt for the kitchen, and even in such quantity that the Bengal vessels, when returning in ballast, take in loadings of this salt *.

The waters of the Dead Sea contain a great deal of the bitumen of Judea, which is nothing but asphaltes; and, accordingly, this sea is often termed the Asphaltic Lake. The neighbouring land is impregnated with this bitumen: and many have imagined, that, like the Lake Avernus, no fishes could live in it, and that birds were suffocated in attempting to fly over it. But such dismal effects are produced by neither of these lakes; for both of them contain fishes, the birds fly over them in safety, and men bathe in them with impunity.

It is said, that, in Bohemia, there is a lake, which has holes in it so deep, that they cannot be sounded, and that, from these holes, there issue violent winds, which sweep over all Bohemia, and, in winter, raise into the air masses of ice

* Descript. de l'Arabie, par M. Niebuhr, p. 2.

of more than 100 pounds weight*. We are likewise told of a petrifying lake in Iceland; and Lake Neagh in Ireland possesses the same quality. But these petrifications are, doubtless, nothing but incrustations similar to those produced by the waters at Arcueil.

* See Act. Leips. anno 1682, p. 246.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XII.

Of the Tides.

WATER, like other fluids, naturally descends from the higher to the lower grounds, if not prevented by some interposed obstacle; and, after it has occupied the lowest situation, it remains smooth and tranquil, unless disturbed by some foreign cause. All the waters of the ocean are collected in the lowest places upon the surface of the earth; and hence the motions of the sea must proceed from external causes. The chief motion is that of the tides, which rise and fall alternately, and from which results a general and perpetual motion, in all seas, from east to west. These two motions have an invariable relation to the motions of the moon. During the full and new moons, this motion from east to west is most

remarkable, as well as that of the tides, which ebb and flow, upon most coasts, every 6¼ hours: it is always high tide when the moon arrives at the meridian, either above or below the horizon of the place; and it is always ebb or low tide when the moon is at the greatest distance from the meridian, or when it rises and sets. The motion from east to west is perpetual; because, when the tide is rising, the whole ocean moves from east to west, and pushes westward an immense body of water; and the ebbing, or reflux, appears only to be owing to the smaller quantity of water which is then impelled towards the west. The flux, therefore, ought rather to be regarded as a swelling, and the reflux as the subsiding of the waters, which, in place of disturbing the motion from east to west, is the cause that produces and renders it perpetual; though this motion, for the reason already mentioned, is greater during the flux than the reflux.

This motion is attended with the following circumstances:

1st, It is more sensible at the full and new moon than at the quadratures; it is likewise more violent in spring and autumn than in any other season; and it is weakest at the solstices. This phænomenon is occasioned by the combined attractions of the moon and sun.

2d, The direction and quantity of this motion is often varied by the winds, especially such as blow constantly from the same quarter. Great rivers, in like manner, by discharging their water into the sea, produce currents which often extend

several leagues, and are strongest when the direction of the wind corresponds with the general motion. Of this an example is afforded in the Pacific Ocean, where the motion from east to west is constant, and very perceptible.

3d, It is worthy of remark, that, when one part of a fluid is moved, the motion is communicated to the whole: during the tides, therefore, a great part of the ocean is sensibly put in motion; and, consequently, the whole ocean, from surface to bottom, is moved at the same time.

To render this more clear, let us attend to the causes which produce the tides. We formerly remarked, that the moon acted upon the earth by a force which some call attraction, and others gravity. This force penetrates the whole globe, is exactly proportioned to the quantity of matter, and decreases as the squares of the distances increase. Let us next examine what effects this force must produce upon the waters, when the moon comes to the meridian of any place. The surface of the water immediately under the moon is then nearer that planet than any other part of the earth; of course, that part of the sea must be elevated towards the moon, and the summit of this eminence must be opposite to the moon's centre. To produce this eminence, the waters upon the surface, as well as those at the bottom, contribute their share, in proportion to their distances from the moon, which acts upon them in the inverse ratio of the squares of their distances. Thus the surface of this part of the sea is first elevated; the surface of the adjacent parts is

likewise elevated, but in a smaller degree; and the waters at the bottom of all these parts are raised by the same cause. Hence, as the whole portion of water under the moon is raised, the waters at a distance, upon which no attraction is exerted, must necessarily rush forward with precipitation to supply the place of those which are elevated, or drawn towards the moon. It is in this manner that the flux, or high tide, is produced, which is more or less sensible on different coasts, and which agitates the sea not only at the surface, but at the greatest depths. The reflux, or ebb, is a consequence of the natural disposition of the water, which, when no longer acted upon by the moon, subsides, and returns to occupy those shores from which it had been forced to retire by a foreign power. The same effect is produced when the moon arrives at the antipode, or opposite meridian, but for a different reason; in the first case, the waters rise, because they are nearer the moon than any other part of the globe; and in the second, they rise, because the moon is at the greatest distance from them. It is easy to perceive that the effect must be the same; for, the waters here being less attracted than those of the opposite hemisphere, they will necessarily recede, and form an eminence, the highest point of which will be where the attraction is least, that is, in the meridian opposite to the moon's station, or to the place where she was thirteen hours before. When the moon comes to the horizon, the tide is ebb, and the sea is in its natural state of equi-

librium. But when she is in the opposite meridian, this equilibrium cannot exist; for the waters, at the place opposite to the moon, being then at their great distance from her, they are less attracted than the rest of the globe; and hence their relative gravity, by which they are constantly kept in equilibrium, pushes them towards the point opposite to the moon, in order to preserve this equilibrium. Thus, in both cases, when the moon is in the meridian of a place, or in the opposite meridian, the waters must be elevated nearly to the same height; and, consequently, they must ebb or flow back when the moon is in the horizon, either at her rising or setting. A motion, such as we have described, necessarily agitates the whole mass of the ocean, from its surface to its bottom; and, as the bottom is less affected by winds than the surface, the motion produced in the former, by the tides, is more regular and uniform.

From this alternate ebbing and flowing, there results, as already remarked, a constant motion of the sea from east to west; for the moon, which is the cause of the tides, moves from east to west, and, by acting successively in this direction, she draws the waters after her. This motion is most perceptible in straits. At the straits of Magellan, for example, the tides rise near twenty feet, and they continue at this height six hours; but the reflux, or ebbing, lasts only two hours, and the waters run to the west *. This incontestibly

* See Narborough's Voyages.

proves, that the reflux is not equal to the flux, and that, from both there results a motion to the west, which is stronger during the flux than the reflux. It is for this reason, that, in open seas, at great distances from land, the tides are only rendered perceptible by this general current of the waters from east to west.

The tides are much higher between the tropics than in any other part of the ocean. They likewise rise higher in places that stretch from east to west, in long and narrow bays, and upon coasts which are interrupted with islands and promontories. The highest known tides take place at one of the mouths of the Indus, where they rise thirty feet perpendicular. They have also a remarkable elevation at Malaya, in the straits of Sunda, in the Red Sea, in Nelson's Bay, at the mouth of the river St. Lawrence, upon the coasts of China and Japan, at Panama, in the gulf of Bengal, &c.

The sea's motion, from east to west, is most observable in particular places. Voyagers have often remarked it in sailing from India to Madagascar and Africa. It moves also with considerable force in the Pacific Ocean, and between the Moluccas and Brazil: but it is most violent in straits: the waters are carried from east to west, through the straits of Magellan, for example, with such rapidity, that their motion is perceptible, at a great distance, in the Atlantic Ocean. It was this circumstance, it is said, that made Magellan conjecture that a strait existed by which there was a communication with the

two seas. In the straits formed by the Manillas, in the channels between the Maldiva islands, and in the gulf of Mexico, between Cuba and Jucatan, there is a constant current from east to west. This motion, in the gulf of Paria, is so violent, that its strait is called the Dragon's Mouth. It is likewise violent in the sea of Canada, in that of Tartary, and in Waigat's Straits, through which it forces enormous masses of ice into the northern seas. The Pacific Ocean runs from east to west through the straits of Japan; the sea of Japan runs towards China; and the Indian Ocean runs westward through the straits of Java, and other islands of India. It is, therefore, evident, that the sea has a general and uniform motion from east to west; and, it is certain, that the Atlantic runs towards America, and that the Pacific Ocean flies from it, as is apparent at Cape Current between Lima and Panama*.

In fine, the tides rise and fall alternately in six hours and a half upon most coasts, though they happen at different hours, according to the climate and the position of particular lands. Thus the coasts of the sea are perpetually beat by the waves; and each tide carries off from the higher grounds small quantities of matter, and deposits them, at a distance, on the bottom of the ocean. In the same manner, each tide carries in, and deposits upon low coasts, sand, shells, and other sea bodies, which gradually form horizontal strata, and give rise to downs,

* See Varen. Geog. p. 119.

and little hills, similar to other hills, both in figure and internal structure. Thus the sea is constantly encroaching upon high coasts, and losing ground upon those that are low; and these effects are produced by the tides, and by violent winds.

To give an idea of the violent effects of a stormy sea against a high coast, I shall relate a fact attested by an eye witness, a person worthy of the highest credit. In the largest of the Orkney islands, there are coasts composed of solid rock, above 200 feet high, and nearly perpendicular to the surface of the water. The tides, as is usual in islands and promontories, rise very high at this place. But, when a violent wind concurs with the flow of the tide, the agitation of the waters is so great, that they often rise above these rocks, and fall down in the form of rain: nay, to this amazing height, gravel, and stones as large as a man's fist, are raised from the foot of the rocks.

I myself saw, in the port of Leghorn, where the sea is much more tranquil, a tempest in December 1791, which obliged the mariners to cut off the masts of their vessels, that were driven, by the violence of the wind, from their anchors in the road; the waters of the sea surmounted fortifications of a great height; and, as I was upon one of the most advanced works, before I could reach the town, I was more drenched with sea water than I could have been by the heaviest rain.

These examples may convey a notion of the

violence with which the sea acts against particular coasts. This constant agitation gradually wears *, corrodes, excavates, and diminishes the quantity of the land. All these materials are transported and deposited in places where the sea is more tranquil. In the time of storms the water is foul and muddy, by the admixture of matters detached from the coasts and from the bottom of the sea. These bodies, which are very various, and carried from great distances, are thrown upon the low shores, especially after tempests, as ambergris on the west of Ireland, yellow amber upon the coasts of Pomerania, cocoas upon the coast of India, &c., and sometimes pumice and other singular stones. On this occasion we may quote a passage from the New Voyages to the islands of America. "When at St. Domingo," says the author, "I was presented, among other things, with some light stones, brought in by the sea in high south winds: some of them were two and a half feet long, eighteen inches broad, and about a foot thick; and yet they weighed not above five pounds. They were as white as snow, harder than pumice, of a fine grain, and appeared not to be porous. When, however, they were thrown into water, they re-

* We are told by Shaw, in his Travels, that, in many parts on the coast of Syria and Phœnicia, the rocks had been cut, by the ancients, into troughs of two or three yards long, and broad in proportion, for the purpose of making salt by evaporation. But notwithstanding the hardness of the rocks, these troughs are now almost totally obliterated by the agitation of the waves.

bounded like a foot-ball thrown against the ground. It was difficult to force them under water with the hand. I inclosed two of these stones with thin boards, and found that they bore 160 pounds without sinking. They served my negro for a shallop, on which he diverted himself in sailing about the quay*." This stone must have been a pumice of a close fine grain, which had been transported by the sea from the neighbourhood of some volcano, in the same manner as ambergris, cocoas, common pumice, the seeds of plants, reeds, &c., are transported. It is chiefly on the coasts of Ireland and of Scotland that observations of this kind have been made. The sea, by its general motion from east to west, ought to carry to America the productions of our coasts; and it must be by the operation of some irregular movements, that the productions of the East and West Indies, and of the northern regions, are brought upon our coasts. The winds are probably the cause of these effects. In open seas, and at great distances from land, large portions of the water have been seen totally covered with pumice-stones. They could only come from volcanos in islands, or on the continent; and they have probably been transported to the open seas by currents. Before the south part of America was discovered, and when it was not believed that the Indian Ocean had any communication with ours, appearances of this kind first gave rise to

* Tom. i. p. 260.

the suspicion that such a communication was not impossible.

The alternate motion of the tides, and the uniform motion of the sea from east to west, exhibit different appearances in different climates, according to the various indentations in the land, and the height of the coasts. In some places, the motion from east to west is not perceptible; at others, it moves in a contrary direction, as on the coast of Guinea. But these contrary motions are occasioned by the winds, by the position of the land, by the waters of great rivers, and by the disposition of the bottom of the sea. All these causes produce currents, which often change the direction of the general movement. But, as this motion from east to west is the greatest, most general, and constant, it ought to produce the most signal effects; and, upon the whole, the sea must gradually gain ground on the west, and lose it on the east; and although, upon coasts where the west wind blows during the greatest part of the year, as in France and Britain, the sea may gain land on the east, yet these exceptions destroy not the effect of the general cause.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XIII.

Of Inequalities in the Bottom of the Sea, and of Currents.

THE coasts of the sea may be divided into three kinds:

1. High coasts, composed of hard rocks, commonly perpendicular, and of a considerable elevation, rising sometimes to the height of 700 or 800 feet.

2. Low coasts, of which some are almost level with the surface of the water, and others have a small elevation, and are often bordered with rocks nearly of a level with the water, which give rise to breakers, and render the approach of ships exceedingly dangerous.

3. Downs or coasts formed by sand, either accumulated by the sea, or brought down and deposited by rivers: these downs form hills

of more or less elevation, according to circumstances.

The coasts of Italy are lined with marble and rocks of different species. These rocks appear at a distance like perpendicular pillars of marble. The coasts of France, from Brest to Bourdeaux, consist almost entirely of rocks on a level with the sea, which occasion breakers. The coasts of England, of Spain, and of many other places, are bordered with rocks and hard stones, except particular spots, which are employed as roads and harbours.

The depth of the water along the coast is generally proportioned to its elevation; a high coast indicates a deep water; and, on low coasts, the water is commonly shallow. The inequalities at the bottom of the sea near the coasts likewise correspond with the inequalities in the surface of the ground along the shore. This subject is illustrated in the following manner by a celebrated voyager.

"I have made it my general observation, that, where the land is fenced with steep rocks and cliffs against the sea, there the sea is very deep, and seldom affords anchor-ground; and, on the other side, where the land falls away with a declivity into the sea (although the land be extraordinary high within), yet there are commonly good soundings, and, consequently, anchoring; and, as the visible declivity of the land appears near, or at the edge of the water, whether pretty steep, or more sloping, so we commonly find our anchor-ground to be more

or less deep or steep; therefore we come nearer the shore, or anchor farther off, as we see convenient; for there is no coast in the world, that I know, or have heard of, where the land is of a continued height, without some small valleys or declivities, which lie intermixed with the high land. They are the subsiding of valleys or low lands, that make dents in the shore and creeks, small bays and harbours, or little coves, &c., which afford good anchoring, the surface of the earth being there lodged deep under water. Thus we find many good harbours on such coasts, where the land bounds the sea with steep cliffs, by reason of the declivities, or subsiding of the land between these cliffs: but, where the declension from the hills or cliffs is not within land, between hill and hill, but as on the coast of Chili and Peru, the declivity is toward the main sea, or into it, the coast being perpendicular, or very steep from the neighbouring hills, as in those countries from the Andes, that run along the shore, there is a deep sea, and few or no harbours or creeks. All that coast is too steep for anchoring, and hath the fewest roads fit for ships of any coast I know. The coasts of Gallicia, Portugal, Norway, and Newfoundland, &c., are coasts like the Peruvian, and the high islands of the Archipelago; but yet not so scanty of good harbours; for, where there are short ridges of land, there are good bays at the extremities of those ridges, where they plunge into the sea; as on the coast of Ca-

raccos, &c. The island of Juan Fernandez, and the island of St. Helena, &c., are such high land with deep shore: and, in general, the plunging of any land under water, seems to be in proportion to the rising of its continuous part above water, more or less steep; and it must be a bottom almost level, or very gently declining, that affords good anchoring, ships being soon driven from their moorings on a steep bank; therefore, we never strive to anchor where we see the land high, and bounding the sea with steep cliffs; and, for this reason, when we came in sight of States-Island, near Terra del Fuego, before we entered into the South Seas, we did not so much as think of anchoring after we saw what land it was, because of the steep cliffs which appeared against the sea; yet there might be little harbours or coves for shallops, or the like, to anchor in, which we did not see, or search for.

" As high steep cliffs bounding on the sea have this ill consequence, that they seldom afford anchoring; so they have this benefit, that we can see them far off, and sail close to them, without danger; for which reason we call them bold shores; whereas low land, on the contrary, is seen but a little way, and in many places we dare not come near it, for fear of running a-ground before we see it. Besides, there are, in many places, shoals thrown out by the course of great rivers, that from the low land fall into the sea.

" This which I have said, that there is usually

good anchoring near low lands, may be illustrated by several instances. Thus, on the south side of the bay of Campeachy, there is mostly low land, and there also is good anchoring all along shore; and, in some places to the eastward of the town of Campeachy, we shall have so many fathoms as we are leagues off from land; that is, from nine to ten leagues distance, till you come within four leagues; and from thence to land it grows but shallower. The bay of Honduras also is low land, and continues mostly so, as we passed along from thence to the coasts of Portobel, and Cartagena, till we came as high as Santa Martha; afterwards the land is low again, till you come towards the coast of Caraccos, which is a high coast and bold shore. The land about Surinam, on the same coast, is low and good anchoring, and that over on the coast of Guiney is such also. And such, too, is the bay of Panama, where the pilot-book orders the pilot always to sound, and not to come within such a deep, be it by night or day. In the same seas, from the high land of Gautimala in Mexico, to California, there is mostly low land and good anchoring. In the main of Asia, the coast of China, the bay of Siam and Bengal, and all the coast of Coromandel, and the coast about Malacca, and against it the island of Sumatra, on that side, are mostly low anchoring shores. But, on the west side of Sumatra, the shore is high and bold; so most of the islands lying to the eastward of Sumatra, as the islands Borneo,

Celebes, Gilolo, and abundance of islands of less note, lying scattered up and down those seas, are low land, and have good anchoring about them; with many shoals scattered to and fro among them; but the islands lying against the East Indian Ocean, especially the west sides of them, are high land and steep, particularly the west parts, not only of Sumatra, but also of Java, Timor, &c. Particulars are endless; but, in general, 'tis seldom but high shores and deep waters, and, on the other side, low land and shallow seas are found together*."

It is, therefore, fully established by the observations of navigators, that there are in the bottom of the sea considerable mountains and other inequalities. We are also assured by the testimony of divers, that there are smaller inequalities occasioned by rocks, and that the cold is greatest in the hollows or valleys. In general, as formerly remarked, the depths of open seas augment in proportion to their distance from the coasts. It appears, from M. Buache's chart of that part of the ocean which lies between the coasts of Africa and America, and from the draughts he has given us of the sea from Cape Tagrin to Rio-grand, that the bottom of the ocean is as irregular as the surface of the land; that abrolhos, where there are *vigies*, and where some of the rocks are on a level with the water, are only the tops of large and high mountains, of which Dolphin Island is one of the most ele-

* Dampier's Voyages, vol. i. p. 422—425.

vated points; that the Cape de Verd islands are likewise the tops of mountains; and that all round these abrolhos and islands, the depth of the sea is unfathomable.

With regard to the qualities of the different soils at the bottom of the sea, little can be said with precision, as all our knowledge is derived from sounding and from divers. We only know, that some places are covered with slime and mud of a considerable thickness, in which anchors can have no hold: it is probable that, in these places, the mud is deposited by rivers. Other parts are covered with sand of different kinds, similar to those upon land. In others are heaps of shells, madrepores, corals, and other productions of insects, just beginning to unite and to assume the form of stones: in others, we find fragments of stones, gravel, and frequently stones and marbles completely formed. In the Maldiva islands, for example, they build their houses with a hard stone raised from some fathoms under water. At Marseilles, very good marble is raised from the bottom of the sea, which, instead of wasting or destroying stones and marble, creates and preserves them: it is the sun, the earth, the air, and the rains, which alone corrupt and destroy these substances.

The bottom of the sea must be composed of the same materials as the surface of the earth, since the very same substances are found on both. At the bottom of some parts of the ocean are vast collections of shells, madrepores, and corals; and we find, upon land, numberless quarries, banks of chalk, and of other substances, mixed

with the same shells, madrepores, and corals; so that, in every view, the dry parts of this globe resemble those covered with the waters, both in composition of materials, and in superficial inequalities.

M. L'Abbé Dicquemare, a learned natural philosopher, has made some observations on this subject, which seem to accord with what I have advanced in my Theory of the Earth.

"Conversations," says the Abbé Dicquemare, "with pilots of all languages, the perusal of charts and soundings both ancient and modern, the examination of such bodies as attach themselves to the plummet, the inspection of coasts, banks, and of the strata which compose the interior parts of the earth, to a depth nearly equal to the length of our common plumb-lines, some reflections which are most analogous to this subject, arising from physics, cosmography, and natural history; have made me suspect, nay, have even convinced me, that, in some places, there must be two different bottoms, the one often covering the other at intervals: the ancient and permanent, which may be called the general bottom, and the other accidental or particular. The first, which ought to form the basis of a general picture, is the soil of the basin that contains the sea. It is composed of the same strata which we every where find in the bowels of the earth, such as marl, stone, clay, sand, shells, all disposed horizontally, and of an equal thickness through a great extent. . . . . Here, we find a bottom of marl: there, a bottom of clay, sand, or rock. Lastly, the number of general bottoms disco-

verable by sounding exceeds not six or seven species. The most extensive and thickest of these strata, being uncovered, or cut perpendicularly, form great spaces in the sea, where we ought to recognise the general bottom, independent of such foreign substances as may be deposited by currents or other causes. There are other permanent bodies which we have not hitherto mentioned: these are those immense masses of madrepores and corals, which often cover a bottom of rock, and those enormous and extended banks of shells, which a rapid multiplication or other causes have accumulated, and which occur in different places, as it were in colonies. One species occupies a certain extent; the succeeding space is occupied by another species, in the same manner as has been remarked with regard to fossil shells, in a great part of Europe, and perhaps every where else. It is by observations on the interior parts of earth, and on such places as the sea leaves uncovered, where we always see particular species reigning over certain districts, that we have been enabled to form some idea of the prodigious number of individuals, and of the thickness of the banks at the bottom of the sea, of which we can only know the surface by our soundings.

" The accidental or particular bottom is composed of immense numbers of the prickles of the sea urchin; of fragments of shells, sometimes corrupted; of crustaceous animals; of madrepores; of sea plants; of pyrites; of gra-

nites rounded by friction; of pieces of mother-of-pearl; of mica; perhaps of talc, to which different names are given, according to their appearances; of entire shells, but in small quantity, and seemingly dispersed through no great extent; of small flints, some crystals, coloured sands, a light slime, &c. All these bodies, disseminated by the currents, the agitation of the waters, and partly proceeding from the rivers, from the sinking of hills or high beaches, and other accidental causes, seldom perfectly cover the general bottom, which appears every instant, when we sound often in the same regions . . . . I remarked, that, during near a century, a great part of the general bottoms of the gulf of Gascony and la Mancha, have suffered little or no change, which supports my opinion concerning the two bottoms *."

To these inequalities at the bottom, we must ascribe the origin of currents: for, if the bottom were uniform and level, there could be no current but the general motion from east to west, and such as might occasionally be produced by the winds. But what incontestibly proves that most currents are produced by the tides, and take their direction from inequalities at the bottom, is, that they uniformly follow the tides, and change their course at every ebb and flow †. This fact is confirmed by the testimony

* Journ. de Phys. par M. Abbé Rozier, Dec. 1775, p. 438.

† See Pietro della Valle on the Currents in the Gulf of Cambaia, vol. vi. p. 363.

of all navigators, who unanimously affirm, that, in those places where the tides are most impetuous, the currents are likewise most rapid.

Thus it is apparent, that the tides give rise to currents, and that they always follow the direction of the opposite hills or mountains between which they run. Currents produced by winds likewise observe the direction of the eminences concealed under the waters; for they seldom run in the direct path of the winds; neither do those produced by the tides invariably observe the course pointed out by their original cause.

To give a distinct idea of the origin of currents, let it be remarked, that they take place in all seas; that some are rapid, and others slow; that some are of great extent both in length and breadth, and others shorter and narrower; that the same cause by which they are produced, whether it be the winds or the tides, frequently bestows on each a difference both in celerity and direction; that a north wind, for example, which ought to produce a general motion towards the south, gives rise, on the contrary, to a number of separate currents, very different, both in their direction and extent, some running south, others south-east, and others south-west; some are rapid, others slow; some long and broad, and others short and narrow: in a word, their motions are so various and combined, that they lose all resemblance to their general cause. When a contrary wind blows, every motion is uniformly reversed; and the

which we have adduced, is sufficient to show, that all our present continents and islands were formerly covered with the waters of the ocean, and throws much light on the theory which I have been endeavouring to establish. It was not enough to have proved that the internal strata of the earth were formed by sediments of the waters; that the mountains were elevated by successive accumulations of these sediments; or, that many strata were impregnated with shells and other productions of the sea. It was still necessary to investigate and assign the real cause of the correspondence in the angles of mountains, which hitherto had never been attempted, but which, when united with the other proofs, forms a connected chain of evidence in support of my theory, as complete as the nature of physical reasoning will admit.

The most conspicuous currents of the ocean are those in the Atlantic, near the coast of Guiney. They extend from Cape Verd to the bay of Fernandpo. They run from west to east, which is contrary to the general motion of the sea; and they are so rapid, that vessels sail in two days from Moura to Rio de Benin, about 150 leagues, but require six or seven weeks to return. It would be impossible to clear these latitudes, were it not by means of the tempestuous winds which suddenly arise in them: but there are sometimes whole seasons in which the mariner is obliged to remain stationary, on account of perpetual calms, the sea having here no motion but what it derives from the currents; and

these always run in upon the coasts, from which they extend not above twenty leagues. Near the island of Sumatra, there are rapid currents, which run from south to north, and which have probably given rise to the bay between Malacca and India. We find similar currents between Java and the lands of Magellan, and between the Cape of Good Hope and Madagascar, especially on the African coast from Natal to the Cape. In the Pacific Ocean, upon the coasts of Peru, and the rest of America, the waters move from south to north, which is probably owing to the constant blowing of the south wind. The same motion from south to north has been remarked on the coasts of Brazil, from Cape St. Augustine to the Antilles, and from the mouth of the Manilla Straits to the Philippines and Japan *.

There are violent currents in the neighbourhood of the Maldiva islands; and between these islands, as already observed, the currents run alternately in opposite directions six months in the year, and are probably occasioned by the trade winds.

To the enumeration of currents, we shall add the famous current of Mosckoe, Mosche, or Male, on the coast of Norway, of which a learned Swede has given the following description:

" This current, which took its name from the rock of Moschensicle, situated between the two

* See Varen. Geogr. p. 140.

islands of Tofode and Woeroen, extends four miles from north to south.

" It is extremely rapid, especially between the rock of Mosche and the point of Lofoede. But, in proportion as it approaches the two isles of Woeroen and Rouest, its rapidity diminishes. It finishes its course from north to south in six hours, and from south to north in an equal time.

" This current is so rapid, that it produces a number of small eddies, which the Norwegians call *gargamer*.

" Instead of following the course of the tides, it observes an opposite direction. When the waters of the ocean rise, they proceed from south to north, but the current then runs from north to south. When the sea retires, it goes from north to south, but the current then runs from south to north.

" It is remarkable, that, both in going and returning, it does not describe a straight line, like other currents found in some straits, where the waters of the sea rise and fall; but it moves in a circular direction.

" When the waters of the sea have risen one half, those of the current run to the south south-east. In proportion as the sea rises, the current turns towards the south; from thence it turns toward the south-west, and from the south-west to the west.

" When the tide is full, the current goes toward the north-west, and then toward the north.

About the middle of the reflux the current recommences its course, after having been suspended during some seconds.

"The principal phænomenon is its return by the west from the south south-east toward the north. If it did not come back by the same road, it would be difficult and almost impossible to sail from the point of Lofoede, to the two great islands of Woeroen and Rouest. There are two parishes, which would necessarily be uninhabited, if the current observed not the course I have described. But, as it actually observes this course, those who pass from the point of Lofoede to the two islands, wait till the tide has risen one half, because the direction of the current is then to the west. When they want to return from these islands to the point of Lofoede, they wait till the tide be half ebb; because the course of the current is then toward the Continent. This circumstance renders the passage very easy. . . . Now, there is no current without a declivity; and here the water rises on one side and descends by the other. . . . . .

To be convinced of this truth, we have only to consider that there is a small tongue of land in Norway, which extends sixteen miles into the sea, from the point of Lofoede, which inclines more to the west, as far as that of Loddinge, which inclines more to the east. This tongue of land is surrounded by the sea; and, whether during the flux or reflux, the water is always stopt there; because it can have no issue but through six small straits or passages,

which divide the tongue of land into an equal number of portions. Some of these exceed not half a quarter of a mile in breadth, and sometimes not half so much. Hence they contain only a small quantity of water. Of course, when the sea rises, a great part of the water coming to the north is stopt to the south of this tongue of land. The waters are, therefore, much more elevated toward the south, than toward the north. When the sea retires, and goes toward the south, a great part of the water, in the same manner, is arrested to the north of this tongue of land, and, consequently, is much higher towards the north, than towards the south.

"The waters, thus interrupted, sometimes at the north and sometimes at the south, can find an issue only between the point of Lofoede and the island of Woeroen, and between this island and that of Rouest.

"The declivity of the waters, when they descend, produces the rapidity of the current; and, for the same reason, this rapidity is greatest towards the point of Lofoede. As this point is nearest the place where the waters are stopt, the rapidity there is likewise greatest; and, in proportion as the waters of the current extend towards the islands of Woeroen and Rouest, their celerity decreases.

"It is now easy to conceive why the current is always diametrically opposite to the motion of the sea. Nothing opposes the common movements of the waters, whether they rise or fall.

But the waters which are stopt above the point of Lofoede can neither move in a straight line, nor beyond this point, while the sea has not descended lower, and has not, in retiring, carried off the waters, which those that are stopt above the point of Lofoede ought to replace. . . . .

"At the commencement of the flux and reflux, the waters of the sea cannot turn back those of the current; but when they have risen or fallen one half, they are then enabled to change the direction of the current. As it cannot then turn toward the east, because the water is always stable near the point of Lofoede, as formerly remarked, it must necessarily proceed toward the west, where the water is lower *."

This explication seems to be conformable to the true principles of the theory of running waters.

We must still add the description of the famous current of Scylla and Charybdis, near the island of Sicily, concerning which Mr. Brydone has lately made some observations, tending to prove that the violence and rapidity of its movements are much diminished.

"It was almost a dead calm, our ship scarce moving half a mile in an hour, so that we had time to get a complete view of the famous rock of Scylla, on the Calabrian side, Cape Pylorus

* Descript. du Courant de Mosckoe, &c. Journal Etranger, Fevrier, 1758, p. 25.

on the Sicilian, and the celebrated straits of the Faro that runs between them. Whilst we were still some miles distant from the entry of the straits, we heard the roaring of the current, like the noise of some large impetuous river confined between narrow banks. This increased in proportion as we advanced, till we saw the water in many places raised to a considerable height, and forming large eddies or whirlpools. The sea in every other place was as smooth as glass. Our old pilot told us, that he had often seen ships caught in these eddies, and whirled about with great rapidity, without obeying the helm in the smallest degree. When the weather is calm, there is little danger: but when the waves meet with this violent current, it makes a dreadful sea. He says, there were five ships wrecked in this spot last winter. We observed that the current set exactly for the rock of Scylla, and would infallibly have carried any thing thrown into it against that point; so that it was not without reason the ancients have painted it as an object of such terror. It is about a mile from the entry of the Faro, and forms a small promontory, which runs a little out to sea, and meets the whole force of the waters, as they come out of the narrowest parts of the straits. The head of this promontory is the famous Scylla. It must be owned, that it does not altogether come up to the formidable description that Homer gives of it; the reading of which (like

that of Shakespear's Cliff) almost makes one's head giddy. Neither is the passage so wonderous narrow and difficult as he makes it. Indeed it is probable that the breadth of it is greatly increased since his time, by the violent impetuosity of the current. And this violence, too, must have always diminished, in proportion as the breadth of the channel increased. The rock is near 200 feet high. There is a kind of castle or fort built on its summit; and the town of Scylla, or Sciglio, containing three or four hundred inhabitants, stands on its south side, and gives the title of prince to a Calabrese family. We lay just opposite to Cape Pylorus, where the light-house is now built. . . . . . The mouth of the straits, betwixt the promontories of Pylorus in Sicily, and the Coda de Volpe in Calabria, appears scarcely to be a mile. But the channel enlarges to four miles in breadth near Messina, which is twelve miles from the mouth of the straits. . . . . The celebrated gulf or whirlpool of Charybdis lies near to the entry of the harbour of Messina, and often occasions such an intestine and irregular motion in the water, that the helm loses most of its power, and ships have great difficulty to get in, even with the fairest wind that can blow. . . . . Aristotle gives a long and formidable description of it in his 125th chapter, De Admirandis, which I find translated in an old Sicilian book I have got here. It begins, 'Adeo profundum, horidumque, spectaculum,' &c., but it

is too long to transcribe. It is likewise described by Homer, twelfth of the Odyssey; Virgil, third Æneid; Lucretius, Ovid, Sallust, Seneca; as also by many of the old Italian and Sicilian poets, who all speak of it in terms of horror; and represent it as an object that inspired terror, even when looked on at a distance. It certainly is not now so formidable; and, very probably, the violence of this motion, continued for so many ages, has by degrees worn smooth the rugged rocks, and jutting shelves, that may have intercepted and confined the waters. The breadth of the straits too, in this place, I make no doubt is considerably enlarged. Indeed, from the nature of things it must be so; the perpetual friction occasioned by the current must wear away the bank on each side, and enlarge the bed of the water.

"The vessels in this passage were obliged to go as near as possible to the coast of Calabria, in order to avoid the suction occasioned by the whirling of the waters of this vortex; by which means, when they came to the narrowest and most rapid part of the straits, betwixt Cape Pylorus and Scylla, they were in great danger of being carried upon that rock. From whence the proverb, still applied to those who, in attempting to avoid one evil, fall into another,

Incidit in Scyllam, cupiens vitare Carybdim.'

Here another light-house is placed to warn

sailors of their approach to Charybdis, as that other on Cape Pylorus is intended to give them notice of Scylla*."

We here notice such currents only as are remarkable both for their extent and their rapidity; because the number of lesser currents is almost infinite. The tides, the winds, and every cause that agitates the waters, produce currents, which are more or less perceptible in different places. We have already remarked, that the bottom of the sea is, like the land, intersected with mountains and valleys, shoals and sand-banks. In all the mountainous places, the currents must necessarily be violent; and, where the bottom is smooth and level, they are almost imperceptible; for the rapidity of a current must augment in proportion to the obstacles with which the waters have to encounter. The current between two chains of mountains will be more or less violent in proportion to their distance. The same thing must happen between two banks of sand, or two adjacent islands. It is, accordingly, remarkable, that in the Indian Ocean, which is intersected with an innumerable quantity of islands and sand-banks, there are every where currents, which, by their rapidity, render navigation extremely dangerous.

Currents are not only occasioned by inequalities at the bottom, but a similar effect is produced by the coasts, from which the waters are

* Brydone's Tour, vol. i. p. 40; &c.

repelled to greater or less distances. This regorging of the waters may be rendered perpetual and violent by particular circumstances: an oblique position, for example, of a coast, its contiguity to a bay or a great river, a promontory, or any particular obstacle to the general movement of the waters, will always give rise to a current: now, as nothing is more irregular than the bottom and the coasts of the sea, 'the number of currents which every where appear ought not to create surprise.

All currents have a determinate breadth, proportioned to the interval between the two eminences which limit them. They run in the same manner as land rivers; they form a channel, and cut their banks in a regular manner, with corresponding angles; in fine, the currents of the ocean have scooped out our valleys, shaped our mountains, and bestowed upon the land, while it remained under the surface of the waters, the form in which it now appears.

If any doubt should remain concerning the correspondence in the angles of mountains, I appeal to the testimony of every man's observation. Every traveller may remark this correspondence in opposite hills, When a hill makes a projection to the right, the opposite one uniformly recedes to the left. Besides, in opposite hills, separated by valleys, there is rarely any difference in their height. The more I observe the contours and elevations of hills, I am the more convinced of the correspondence of their angles, and of their resemblance to the channels

and banks of rivers. It was the repeated observation of this surprising regularity and resemblance that first suggested the idea of the theory of the earth which I am now supporting. When to this are added the parallelism of the strata, and the shells so universally incorporated with different materials, no subject of this nature can admit of a greater degree of probability.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XIV.

Of Regular Winds.

IN our climates, nothing can appear to be more capricious and irregular than the force and direction of the winds. But there are some countries where this irregularity is not so great, and others where the wind blows constantly in the same direction, and with nearly the same degree of force.

Though the motions of the air depend on many causes; yet there are some more constant and powerful than others. But it is difficult to estimate their precise effects, because these are often modified by secondary causes.

The heat of the sun is the most powerful cause of winds: it produces a considerable and successive rarefaction in the different parts of the atmosphere, and gives rise to an east wind, which

blows constantly between the tropics, where the rarefaction is greatest.

The force of the sun's attraction upon the atmosphere, and even that of the moon, are inconsiderable when compared with the cause just mentioned. This force, it is true, produces a motion in the air similar to that of the tides in the sea: but, though the air is elastic, and 800 times lighter than water, the motion produced by attraction cannot exceed what is excited in the waters of the ocean by the same cause; for the action of gravity being proportioned to the quantity of matter, it must elevate a sea of water, of air, or of quicksilver, nearly to the same height. Hence the influence of the planets upon the air must be inconsiderable*; and, though it must occasion a slight motion from east to west, this motion becomes altogether insensible when compared with that produced by the heat of the sun: but as the rarefaction is always greatest when the sun is in the zenith, the current of air must follow the course of the sun, and produce a constant wind from east to west. At sea, this wind blows perpetually in the torrid zone; and at land, in most places, between the tropics. It is this wind which we perceive when the sun rises; and, in general, east winds are more frequent and more violent than west winds. The general wind, from east to west, extends even beyond the

* See Reflections sur la Cause Generale des Vents, par M. D'Alembert.

tropics. It blows so constantly in the Pacific Ocean, that the ships coming from Acapulco to the Philippines, perform their voyage, which is more than 2,700 leagues, without the least danger, and almost without the necessity of being directed. In the Atlantic, between Africa and Brazil, this wind is equally constant. It is likewise felt between the Philippines and Africa; but there it is less constant, on account of the obstacles it meets with from the numerous islands in that sea; for it blows, during the months of January, February, March, and April, between the Mozambique coast and India; but it gives place to other winds during the rest of the year: and, though it is less perceptible on the coasts than on the open sea, and still less in the interior parts of continents than on the coasts, yet, in some places, it blows almost perpetually, as on the east coasts of Brazil, of Loango in Africa, &c.

This wind is constant under the line; and, therefore, in going from Europe to America, mariners direct their course southward, along the coasts of Spain and Africa, till they come within twenty degrees of the equator, where they fall in with the east, or trade wind, which carries them directly to the coast of America. By means of the same wind, the voyage from Acapulco to the Philippines is performed in two months; but the return from the Philippines to Acapulco is much more difficult, and requires a longer time. About twenty-eight or thirty degrees on this side of the line, the west wind is

equally constant; and, for this reason, the vessels returning from the West Indies to Europe, observe not the same route as in going out. Those from New Spain run north along the coast till they arrive at the Havannah, in the island of Cuba; and from thence they proceed northward, till they fall in with the west wind, which carries them to the Azores, and then to Spain. In the same manner, vessels returning by the South Sea, from the Philippines or China, to Peru or Mexico, sail north as far as Japan; and, under that latitude, they proceed till they arrive at a certain distance from California; and from thence, following the coast of New Spain, they reach Acapulco. These east winds blow not always from the same point; but, in general, they blow from the south-east from April to September, and from the north-east from November to April.

The east wind, by its constant action, augments the general motion of the sea from east to west. It also produces perpetual currents, some of them running from east to west, and others from east to south-east, or north-west, according to the direction of the eminences, or chains of mountains, below the surface: the valleys or intervals between them serve as channels to these sea rivers. The variable winds, which blow sometimes from the east, and sometimes from the south, likewise produce currents, which change their direction with that of the wind.

The winds that blow constantly for some months are commonly succeeded by contrary winds, which oblige the mariner to wait for that which is most favourable to his destination. When these winds change, they often produce, for several days, and sometimes for a month, or even two months, a perfect calm, or dreadful tempests.

These general winds, occasioned by the rarefaction of the atmosphere, are variously combined and modified by different causes, and in different climates. In that part of the Atlantic which lies under the temperate zone, the north wind blows almost constantly during the months of October, November, December, and January. These months, therefore, are most favourable for ships going to the Indies, which are carried over the line by this wind: and it is a well known fact, that vessels which depart from Europe in March, frequently arrive not sooner at Brazil than those which set out in the following October. The north wind reigns almost perpetually, during the winter, off Nova Zembla, and other northern coasts. At Cape de Verd, the south wind blows during the month of July, which is the rainy season, or winter, in that climate. At the Cape of Good Hope, the north-west wind blows during the month of September: the same wind blows at Patna in the East Indies during the months of November, December, and January, and occasions great rains; but the east wind prevails during the other nine

months. In the Indian Ocean, between Africa and India, and as far as the Molucca islands, the trade wind from east to west reigns from January to the beginning of June; the west winds begin in August or September; and, in the interval between June and July, there are dreadful tempests, generally from the north winds; but these winds are more variable on the coasts than in the open seas.

In the kingdom of Guzarat, and upon the neighbouring coasts, the north winds blow from March to September; and, during the other months, the south winds almost always prevail. The Dutch, in returning from Java, set out in January or February, by the assistance of the east wind, which is felt as far as the eighteenth degree of south latitude; and then they meet with south winds, which carry them to St. Helena *.

Some regular winds are produced by the melting of the snows. This was remarked by the ancient Greeks. During summer a north-east wind, and a south-east one during winter, was observed to take place in Thracia, in Macedonia, in the Egean Sea, and even in Egypt and Africa; and winds of the same kind have been remarked in Congo, at Guzarat, and at the extremity of Africa, which are all occasioned by the melting of the snows. Regular winds, which last but a few hours, are also produced by the motion of the tides; and, in many places,

* See Varen. Geogr. cap. 20.

as on the coasts of New Spain, of Congo, of Cuba, &c., a wind blows from the land during the night, and from the sea during the day.

The north winds are equally regular within the polar circles; but they become more and more imperceptible as we approach the equator: this remark is applicable to both poles.

In the Atlantic and Ethiopic Ocean, within the tropics, an east wind blows during the whole year, without any considerable variation, except in some small spots, where it changes according to the situation of coasts, and other circumstances: 1st, Near the coast of Africa, and about the twenty-eighth degree of north latitude, vessels are certain of finding a fresh gale from the north-east or north north-east, which accompanies them to the tenth degree of the same latitude, about 100 leagues from the coast of Guinea; and at the fourth degree of north latitude, they meet with calms and tornadoes. 2d, In going by the Caribbee islands, this wind turns more and more easterly, in proportion as vessels approach the American coast. 3d, The limits of these variable winds, in the Atlantic, are more extensive upon the coasts of America than upon those of Africa. Along the coast of Guinea, from Sierra Leona to the island of St. Thomas, an extent of about 500 leagues, there is a perpetual south, or south-west wind. The narrowest part of the Atlantic is from the coast of Guinea to Brazil, where it is not above 500 leagues over. Vessels, however, that depart from Guinea, are obliged to shape their course

southward, especially when they set out in the months of July or August, in order to fall in with the south-east winds, which blow constantly during this season *.

In the Mediterranean, the east wind blows from the land in the evening, and the west wind from the sea in the morning. The south wind, which is accompanied with rain, and blows commonly during the latter end of autumn, at Paris, in Burgundy, and Champagne, yields to a mild north-east wind, which produces that fine weather vulgarly called Saint Martin's Summer †.

Doctor Lister alleges, that the east wind, which reigns during the whole year between the tropics, is occasioned by the transpiration of the plant called the sea lentil, which abounds in these climates; and that the difference of land winds is owing to the different situation of trees and forests. This ridiculous whim he assigns as the cause of the winds; and, in his opinion, the wind is strongest at mid-day, because the transpiration from plants is then greatest; and the wind, continues he, blows from east to west, because all plants are, in some measure, sun-flowers, and transpire most from the side opposed to the sun ‡.

Other authors have assigned the diurnal motion of the earth as the cause of this east wind.

* See Phil. Trans. Abridg. vol. ii. p. 129.

† See Traité de Eaux de M. Mariotte.

‡ See Phil. Trans. No. 156.

This notion is specious: but every man, who has the least knowledge of physics, must allow, that no fluid which surrounds the earth can be affected by its rotation; that the air must move along with the earth itself; and that the rotatory motion is equally imperceptible in the atmosphere as on the surface of the earth.

The principal cause of the winds, as already remarked, is the heat of the sun *; for whatever rarifies or condenses the air, must produce a wind, or current, in a direction opposite to those places where the rarefaction or condensation is greatest.

The pressure of clouds, exhalations from the earth, the explosion of meteors, rains, &c., likewise produce considerable agitations in the atmosphere. Each of these causes, when variously combined, produce different effects. As it is in vain to attempt a complete theory of the winds, I confine myself to their history.

If we had a series of observations upon the direction, the force, and the variations of the winds in the different climates of the earth, and if these observations were sufficiently numerous and exact, we might be enabled to form more complete ideas with regard to the causes of the different changes in the atmosphere.

The winds are more regular at sea than upon land; because their motion is not interrupted. But, upon land, the direction is frequently changed by the interposition of mountains, fo-

* See Halley's Treatise on this subject in the Phil. Trans.

rests, cities, and other obstacles. Winds are often reflected from mountains with a force nearly equal to that of their original current: these winds are exceedingly irregular, because their direction depends on the contour, the height, and the situation of the mountains from which they rebound. The sea winds also blow with more force and uniformity, and last longer: the land winds, however violent, have intermissions, and moments of repose: but, at sea, the current of the air, having no obstacles to contend with, is uniform and perpetual.

At sea, the east winds, and those which come from the poles, are generally stronger than the west winds, and those that proceed from the equator. But, at land, the south and west winds are more or less violent, according to the different situation of particular countries. During spring and autumn, the winds, both at sea and land, are more violent than in summer or winter. For this fact, several reasons may be assigned: 1. In spring and autumn the tides are highest; and, consequently, the winds they excite are most violent during those seasons. 2. The motion produced in the atmosphere by the action of the sun and moon, or the tides of the air, must likewise be greatest about the equinoxes. 3. The melting of the snows in spring, and the condensation of the vapours exhaled in summer by the sun, and which fall down in the autumn in the form of rain, produce, or at least augment, the force of the winds. 4. The transition from heat to cold, or from cold to heat, must create con-

siderable augmentation and diminution in the volume of the air, which alone is sufficient to raise great winds.

Contrary currents in the atmosphere have often been remarked. We see some clouds moving in one direction, and others, either above or below them, proceeding in a direction perfectly opposite. This contrariety of motion never continues long; because its general cause is the resistance of some large cloud, which reflects the wind in a direction opposite to its natural course, but is soon dissipated.

The wind is more violent in proportion to the elevation of the ground, till it arrives at the ordinary station of the clouds, which is about one fourth or one third of a league perpendicular height; and beyond this, the sky is generally serene, especially in summer, and the wind gradually diminishes: it is even said to be altogether imperceptible on the tops of the highest mountains. However, as the summits of these mountains are covered with ice and snow, it is natural to think that this region of the air is agitated during the fall of the snows, and that the winds are imperceptible in the summer season only. The light vapours which are raised in summer fall in the form of dews; but, in winter, they are condensed, and fall on the tops of the mountains in the form of snow or ice, which may raise considerable winds at that altitude.

It has been proved, by a thousand experiments, that the higher we rise above the level of the sea or of plains, the column of mercury in the ba-

rometer sinks the lower; and, consequently, that the weight of a column of air diminishes in proportion to the elevation of the place; and as air is an elastic and compressible fluid, philosophers have unanimously concluded from these experiments, that the air is much more dense and compressed in the plains, than on the tops of mountains. For example, if the barometer, which stands at twenty-seven inches in the plain, falls, on the top of a mountain, to eighteen, a difference of one third of the whole weight of the column of air, we say, that, the compression of this element being always proportioned to the incumbent weight, the air at the top of the mountain is, of course, one third less dense than that in the plain, because it is compressed by a weight one third less. But strong reasons concur in making me suspect the truth of this conclusion, which has hitherto been regarded as natural, and perfectly legitimate.

Let us, for a moment, abstract this compressibility of the air, which several causes may augment or diminish, destroy or compensate: let us suppose the air to be every where equally dense; if its thickness exceeded not three leagues, it is certain, that, in mounting one league, the barometer, being loaded with one third less weight, would descend from twenty-seven to eighteen inches. Now the air, though compressible, appears to me to be equally dense at all heights; and this opinion I shall support by the following facts and reasonings.

1. The winds are equally strong and equally

violent at the tops of the highest mountains as in the lowest valleys. With regard to this fact all observers are agreed. Now, if the density of the air were one third less, the action of the wind would necessarily be one third weaker, and all the winds at the height of a league would be only zephyrs, which is absolutely contradicted by uniform experience.

2. Eagles, and several other birds, not only fly to the tops of the highest mountains, but rise to great heights above them. Now I ask, if these animals could either fly, or even support themselves, in a fluid one third less dense than common air, and if the weight of their bodies, notwithstanding all their efforts, would not oblige them to sink lower?

3. All observers, who have climbed to the tops of the highest mountains, agree that they respire as freely as in any other situation, and that the only inconveniency they feel arises from the cold, which augments in proportion to the elevation. Now if the air was one third less dense at the tops of mountains, the respiration of man, and of birds which mount still higher, would not only be injured, but stopped, as actually happens to animals in an air pump, when one fourth or one third of the air contained in the receiver is exhausted.

4. As cold condenses as much as heat rarefies the air, and as, in proportion to the elevation of mountains, the cold increases, does it not follow, that the degrees of condensation of the air correspond to the degrees of cold? This con-

densation may equal, and even surpass that of the air in plains, where the heat escaping from the internal parts of the earth is much greater than at the tops of mountains, which are the most advanced and coldest points on the surface of the globe. Hence this condensation of the air by cold, in high regions of the atmosphere, should compensate the diminution of density produced by a decrease of the incumbent weight; and, of course, the air should be equally dense on the cold summits of mountains as in the plains. I am even led to think, that the air is more dense on the tops of mountains, because there the winds seem to be more violent, and the birds which soar above the highest summits appear to support themselves in the air with more ease in proportion to the height they rise.

I may therefore conclude, that the free air is nearly of equal density at all heights, and that the atmosphere extends not so high as has been determined, by considering the air as an elastic mass compressed by an incumbent weight. Thus the total thickness of the atmosphere may not exceed three leagues, instead of from fifteen to twenty, as has been conjectured by philosophers *.

* Alhazen, from the duration of the twilights, pretended that the height of the atmosphere is 44,331 fathoms. Kepler, upon the same principle, makes it 41,110 fathoms.

M. de la Hire, when treating of the horizontal refraction of thirty-two minutes, fixes the mean height of the atmosphere at 34,585 fathoms.

M. Mariotte, from his experiments on the compressi-

The first stratum of the atmosphere is filled with vapours exhaled from the surface of the globe, both by its own heat and that of the sun. In this stratum, which extends to the height of the clouds, the heat arising from exhalations produces and supports a rarefaction that forms an equipoise to the superior air; so that the lower stratum of the atmosphere is not so dense as it ought to be in proportion to the pressure it receives. But, at the height where this rarefaction ceases, the air undergoes all that condensation which is produced by the cold of this region, where the heat arising from the earth is much *diminished*; *and this condensation appears to be even greater than that which might be produced, by the weight of the superior strata, in the inferior regions*, which are supported by rarefaction. This idea is strengthened by another phænomenon, which is the condensation and suspension of the clouds in that elevated region where they are formed and supported. Beyond this middle region, where the cold and condensation commence, the vapours rise, but cease to be visible, except when a part of a cold stratum seems to be pushed back toward the

bility of air, makes the height of the atmosphere 30,000 fathoms.

However, comprehending under the atmosphere that part of the air only in which refractions take place, M. Bouguer ascertains the height not to be above 5,158 fathoms, *i. e.* two and a half or three leagues; and I believe that this result is more certain and better founded than any of the others.

surface of the earth, and when the heat escaping from the earth being for some time extinguished by rains, the vapours then collect and thicken around us in the form of mists and fogs. Without these circumstances, the vapours never become visible till they arrive at that region where the cold condenses them into clouds, and stops their farther ascension: their gravity, which augments in proportion as they become more dense, fixes them in an equipoise which they cannot surmount. We perceive that the clouds are generally higher in summer, and still higher in warm climates. It is in this season and in *these climates that the stratum formed by evapo*ration from the earth rises highest. On the contrary, in the frozen regions near the pole, where the evaporation produced by the heat of the globe is much less, the stratum of dense air seems to touch the surface, and there to retain the clouds, which never rise higher, but surround these gloomy regions with perpetual fogs.

The celerity of a current of air is augmented when its passage is contracted. The same wind, which is but slightly felt in a large open plain, becomes violent in its progress through a narrow pass in a mountain, or between two high houses; and it is most violent at the tops of the buildings or of the mountain, because the air, being compressed by these obstacles, is augmented both in volume and density; and, as its celerity remains the same, its force or momentum must be increased. It is for this reason that the wind ap-

pears to be more violent near a church or a tower than at a distance from them. I have often remarked, that the wind reflected from a building standing by itself, is stronger than the direct wind by which it was produced. This effect can be owing to no other cause than the compression of the air against the building, from which it rebounds.

I shall here mention a fact which seems to have escaped the observation of natural philosophers, though every man is in a condition to convince himself of its truth. The fact is, that the reflected wind is more violent than the direct, and still more so in proportion to the nearness of the obstacle by which it is reflected. I have often made the experiment by approaching a tower, of near 100 feet high, and situated at the north of my garden at Montbard. When a strong south wind blows, we are violently pushed back, at the distance of thirty paces: after which, there is an interval for five or six paces, where the violence of the reflected wind ceases, and seems to be in equilibrium with the direct. The nearer we approach, the strength of the reflected wind augments, and pushes us back with much greater force than the direct wind pushes us forward. The cause of this general effect, which may be perceived opposite to any high buildings, precipices, &c., it is not difficult to discover. The air in the direct wind acts only by its celerity and its common volume; but this volume or mass is considerably augmented by the compres-

sion it receives from the obstacle by which it is reflected; and, as the quantity of every motion consists of the celerity multiplied by the volume, this quantity is much greater after being compressed than before. It is a volume of common air which acts in the first case, and a volume of air of double or triple the density which acts in the second.

As the density of the air is greatest at the surface of the earth, it is natural to conclude, that the wind must there also be most violent; and this conclusion is, I apprehend, just, when the sky is serene: but, when it is charged with clouds, the action of the wind will be most violent at the height of the clouds, which are denser than air, as they fall in the form of rain or of hail. In computing the force of wind, therefore, we ought to estimate not only its velocity, but likewise the density of the air; for two winds, of equal velocities, may differ greatly in their force, if the densities of the air be unequal. From this remark, we may learn the imperfection of those machines which have been employed for measuring the velocity of the winds.

Particular winds, whether they be direct or reflected, are more violent than those which are general. The interrupted action of land winds depends on the compression of the air, which renders every blast more violent than if the current were uniform. A uniformly continued stream of air produces not such havoc as the

is from the end of June to the beginning of August, the sea is infested with violent tempests from the north.

"These winds are subject to the greatest variations near the coasts: vessels cannot take their departure from the coast of Malabar, and other ports on the west coast of the peninsula of India, to Africa, Arabia, or Persia, but from the month of January to April or May; for, at the end of May, and during the months of June, July, and August, the tempests from the north and north-east are so violent, that no ships can keep the seas. But, on the other side of this peninsula, in the sea which washes the coast of Coromandel, there are no tempests of this kind.

"Vessels depart from Java, Ceylon, and several other places, for the Moluccas, in September, because the west wind begins then to blow in these regions. However, when fifteen degrees south of the equator, this wind ceases, and they fall in with the trade wind, which, in this place, blows from the south-east. In the same manner, vessels depart from Cochin for Malacca in March; because, at this time, the west wind begins to blow. Thus the west winds arise at different times, in different parts of the Indian Ocean. The times of departure are different from Java to the Moluccas, from Cochin to Malacca, from Malacca to China, and from China to Japan.

"At Banda, the west winds terminate at the

end of March; calm and variable winds occupy the month of April; and the east winds begin with great violence in May. At Ceylon, the west winds commence about the middle of March, and continue to the beginning of October, when the east, or rather east north-east winds, return. At Madagascar, they have north or north-west winds from the middle of April to the end of May; but east and south winds in February and March. From Madagascar to the Cape of Good Hope, the northerly winds prevail during the months of March and April. In the gulf of Bengal, after the 20th of April, the south winds blow with violence; and, before this period, the south-west and north-west winds prevail. The westerly winds are also violent in the Chinese sea during the months of June and July. This is, therefore, the most proper season for sailing from China to Japan: but, in returning from Japan to China, February and March are preferable, because the easterly winds then prevail.

"There are some winds which may be considered as peculiar to certain coasts: for example, a south wind blows almost perpetually on the coasts of Chili and Peru. It begins about the forty-sixth degree of south latitude, and extends beyond Panama, which makes the voyage from Lima to Panama more easy and expeditious than the return. The westerly winds blow almost continually on the coasts of Ma-

gellan's land, in the neighbourhood of the straits of La Maire. Upon the Malabar coast, they have almost constantly north and north-west winds. The north wind is very frequent on the coast of Guinea. The westerly winds reign upon the coasts of Japan during the months of November and December."

The periodic, or alternate winds, mentioned above, are peculiar to the sea. But upon land there are also periodic winds, which return at certain seasons or particular days, or even at stated hours. On the coast of Malabar, for example, an easterly land wind blows from September to April: it generally commences at midnight, and ends at noon; and it is not perceptible at twelve or fifteen leagues from the coast. From noon to midnight, there is a gentle westerly breeze from the sea. Upon the coasts of New Spain in America, and upon those of Congo in Africa, land winds blow during the night, and sea winds during the day. Winds blow from all the coasts of Jamaica during the night, which prevents the landing, or sailing of ships with safety, before the rising of the sun.

In winter, the port of Cochin is inaccessible; neither can any vessel get out; because the winds are so impetuous, that no vessels can keep the sea; and, besides, the west wind, which blows with great fury, drives such a quantity of sand into the mouth of the river, as renders it impossible for ships of any burthen to enter it for six

months of the year. But the east wind, which blows during the other six months, drives back the sand into the sea, and opens the mouth of the river. At the straits of Babelmandel, there is a south-east wind, which is regularly succeeded by the north-east. At Saint Domingo, there are two different winds, that rise regularly every day: the one, which is from the sea, comes from the east, and begins at ten o'clock before noon; the other, which is a land wind, from the west, rises at six or seven in the evening, and continues the whole night*. Other facts of this

* There are certain climates and particular countries, where the winds vary regularly; some at the end of six months, others in a few weeks, others from morning to night, and from night to morning. M. Fresnaye writes me, that "the two regular winds, which blow at St. Domingo, are both from the sea, and blow, the one in the morning from the east, and the other in the evening from the west, which is only the same wind returned. It is evidently occasioned by the sun; for, every man perceives, that between one and two o'clock after noon, a transient gust arises. When the sun declines, by rarefying the air on the west, it drives to the east the clouds which the morning wind had confined toward the opposite quarter. These returned clouds, from April or May till toward autumn, produce in the district of Port-au-Prince the regular rains which constantly proceed from the east. There is not a single inhabitant who does not predict the evening rain between six and nine o'clock, when, according to their mode of expression, the broken cloud has been sent back. The west wind continues not during the whole night. It falls regularly toward the evening, and, when it ceases, the clouds pushed from the east are enabled to fall in the form of rain, as soon as their weight exceeds that of an equal column of air. The wind which prevails in the night is a land wind, which proceeds neither from the east nor the west, but fol-

kind, collected from voyagers of knowledge and credit, might furnish a complete history of the winds, which would be a work extremely useful, both in navigation and physics.

lows the projections of the coast. At Port-au-Prince, the south wind, because it traverses the course of the river, is intolerably cold during the months of January and February *."

* Note communicated to M. de Buffon, by M. Fresnaye, one of the counsellors of St. Domingo, dated March 10, 1777.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XV.

Of Irregular Winds, Hurricanes, Water Spouts, and other Phænomena, occasioned by the Agitations of the Sea, and of the Air.

THE winds are more irregular on the land than on the sea, and in high than in low countries. The mountains not only change the direction of the winds, but even produce some, which are either constant or variable, according to their causes. The melting of snows on the tops of mountains generally gives rise to constant winds, which last a considerable time. The vapours that strike against the mountains, and accumulate upon them, produce variable winds, which are very common in all climates; and there is as great a variety in the motions of the air, as there are inequalities on the surface of the earth. We can, therefore, give exam-

ples only, and a genuine history of facts: and, as a connected series of observations upon the variations of the winds, and even of the seasons, in different countries, is still wanting, we shall not attempt to explain all the causes of these variations, but shall confine ourselves to those which are most probable.

In high mountains, there are winds produced by accidental causes, and particularly by *avalanches*. In the environs of the Alpine glaciers, several species of *avalanches* are distinguishable; some of them are called *windy avalanches*, because they produce a great wind. They are formed when a new fall of snow has been put in motion, either from melting below by the interior heat of the earth, or by the agitation of the air. The snow then forms itself into balls, and in rolling accumulates, falls in vast masses into the valleys, and produces a great agitation in the air; because the snow runs with rapidity, and in immense volumes, and the winds occasioned by the motion of these masses are so impetuous, that they overturn every thing, even the largest pines, that oppose their passage. These *avalanches* cover the whole territory, over which they extend with a very fine snow; and this powdered snow rises in the air at the caprice of the wind, *i. e.* without any fixed direction, which is extremely dangerous to people in the fields; because they know not to what side to run in order to protect themselves; for, in a few seconds, they find themselves surrounded, and often completely buried with the snow.

Another species of *avalanches*, still more dangerous than the first, is called by the country people schlaglawen, *i. e. dashing* or *striking avalanches*. They proceed not with such rapidity as the first kind; but they overturn every thing in their way, and carry along with them great quantities of earth, stones, flints, and even entire trees; so that their passage from the mountain to the valley is a vast track of destruction and ruin. As they proceed with less rapidity than the *avalanches* composed of pure snow, they are more easily avoided. Their approach is announced at a distance: for they shake the mountains and the valleys by their motion and weight, and produce a noise equal to that of thunder.

These tremendous effects may proceed from very slight causes: a small quantity of snow falling from a tree or a rock, the sound of bells, or the shock of a cannon or musket, provided they detach some portions of snow from the summit, which form into balls, and increase in magnitude as they descend, will accumulate into a mass as large as a small mountain before they arrive at the valley.

The inhabitants of countries subject to *avalanches* have invented several precautions to prevent their destructive effects. They place their buildings opposite to small eminences, which may break the force of the *avalanches*. They likewise make plantations of wood before their habitations. At Mount St. Godard, there is a forest in a triangular form, the acute angle of

which is directed towards the mountain, and seems to have been planted with a view to turn off the *avalanches* from the village of Urseren and the buildings situated at the foot of the mountain; and every person is forbid, under the severest penalties, to injure the forest, which may be regarded as the safeguard of the village. With the same intention there are, in many places, walls erected with their acute angles turned toward the mountain. A wall of this kind may be seen at Davis, in the country of the Grisons, as also near the baths of Leuk or Louache in Valais. In the same country of the Grisons, and other places, there are, in the passages through the mountains, vaults at convenient distances, cut out of the rock on the side of the highway, which serve passengers as places of refuge against the *avalanches* *.

In straits, at the extremities of promontories, peninsulas, and capes, and in all narrow bays, tempestuous winds are frequent. But, independent of these, some seas are much more infested with storms than others. The Indian Ocean, the seas of Japan and of Magellan, along the African coast beyond the Canaries, and the opposite coast near Natal, and the Red and Vermilion Seas, are all subject to tempests. The Atlantic is likewise more tempestuous than the great ocean called the Pacific: this last ocean, however, is no where perfectly tranquil, except between the tropics; for the nearer we approach

* Hist. Nat. Helvitique, pur Scheuchzer, tom. i. p. 155.

the poles, it is the more subject to variable winds, the sudden changes of which produce tempests.

All continents are subject to the effects of variable winds, which are sometimes very singular. In the kingdom of Cassimir, which is surrounded with the mountains of Caucasus, a most sudden reverse of seasons is felt on Mount Pirepenjale. In less than an hour's journey, we pass from summer to winter: a north and a south wind, according to Bernier, blow perceptibly within 200 paces of each other. The position of this mountain must be singular; and, therefore, it merits a particular examination. In the peninsula of India, which is traversed from north to south by the Gauts, the extreme heats of summer are felt on one side of those mountains, and all the rigours of winter on the other. The same phænomenon takes place on the two opposite coasts of Cape Rosalgate in Arabia: on the north coast the sea is calm and tranquil; while the south coast is infested with continual storms. Ceylon exhibits another example of this phænomenon. Winter and high winds reign in the north part of the island, while, on the south of it, fine weather and summer heats prevail. Of opposite seasons in the neighbourhood of each other, and at the same time, there are several examples, not only on the continent, but on the islands, as at Cerem, a long island near Amboyna, in the north part of which it is winter, and summer in the south

part; and the interval between these two seasons is not above three or four leagues.

The Russian voyagers have remarked, that, in the entry to the territory of Milim, there is, on the left of the river Lena, a great plain entirely covered with overturned trees, and that all these trees lie in a direction from south to north for an extent of several leagues; so that the whole district, formerly covered with trees, is now strewed with dead trunks in the above direction from south to north. This effect of the south winds has likewise been observed in other northern regions.

In Greenland, and particularly in the autumn, the winds are so impetuous, that the houses are often shaken to pieces, and the boats and tents carried up into the air. The Greenlanders even assure us, that, when they go out to secure their boats, they are obliged to creep on their bellies, lest they should become the sport of the winds. The most violent tempests come from the south, turn to the north, and then terminate in a calm. It is on these occasions that the ice in the bays is raised from its bed and dispersed in small portions over the ocean *.

In Egypt, a south wind prevails during summer, which is so hot as to stop respiration; and it raises such immense quantities of sand, that the sky seems to be covered with thick clouds. This sand is so fine, and is blown with such violence,

* Hist. Gen. des Voyages, tom. xviii. p. 22.

that it penetrates the closest chests. When this wind continues for several days, it gives rise to epidemic diseases, which frequently cut off vast numbers of men. It seldom rains in Egypt; every year, however, there are some days of rain in the months of December, January, and February. But thick fogs are more frequent than rain, especially in the neighbourhood of Cairo. These fogs commence in November, and continue during the winter; and through the whole year, even when the sky is serene, the dews fall so copiously, that they have all the effects of rain.

In Persia, the winter commences in November, and lasts till March. The cold is strong enough to produce ice; and snows fall in the mountains, and sometimes in the plains. From March to May, there are violent winds, which recal the warmth of summer. From May to September the sky is serene, and the heats are moderated during the night by fresh breezes, which continue till morning; and, in autumn, there are violent winds, like those which blow in the spring. However, though these winds are very strong, they seldom produce tempests or hurricanes. But, in summer, a very noxious wind blows along the Persic Gulf, which is called *Samiel* by the natives; it is still hotter and more terrible than that of Egypt; and, as it acts like an explosion of inflamed vapour, it suffocates every person who unhappily falls within its vortex. A similar wind rises in summer along the Red Sea, which suffocates animals, and transports such quantities of sand, that many

people imagine this sea will, in the course of time, be completely filled up. Arabia gives birth to frequent clouds of sand, which darken the air, and excite dangerous whirlwinds. At Vera Cruz, when the hot winds blow from the north, the houses of that town are almost buried with sand. Hot winds are also felt in summer at Negapatam in India, and likewise at Petapouli and Masulapatam. These scorching winds, which kill men, are fortunately of no long duration; but they are extremely violent, and their heat and deleterious quality are proportioned to their velocity, which is contrary to the nature of other winds; for the more their rapidity, they are the more wholesome and refreshing. This difference proceeds from the degree of heat in the air. When the heat of the air is less than that of the body, the motion of the air is agreeable. But, when the heat of the air is greater than that of the bodies of animals, its motion scorches and suffocates. At Goa, the winter, or rather the rainy and tempestuous season, is in the months of May, June, and July, and it cools and refreshes the air, which would otherwise be perfectly insupportable in that region.

The Cape of Good Hope is famous for its tempests, and a peculiar cloud which produces them. This cloud at first appears like a small round spot in the heavens, which mariners distinguish by the name of the Ox's Eye. Its seeming smallness is probably owing to its great height. Of all voyagers who mention

the Ox's Eye, Kolbe appears to have examined it with the greatest attention. "This cloud," says he*, "which appears on the mountains of the Table, or of the Devil, or of the Wind, is composed, if I am not deceived, of an infinite number of particles, pushed, in the first place, against the mountains to the east of the Cape, by the east wind which blows in the torrid zone during almost the whole year. These particles or vapours are stopped by the high mountains, and are collected on their east side. They then become visible in the form of small fragments of clouds, which, by the constant action of the east wind, are elevated to the tops of the mountains. Here they remain not long at rest; but, being forced to advance, they sink down between the mountains, which are still before them, where they are locked up and squeezed on all sides, as in a canal. The wind presses these vapours from above, and the opposite sides of the two mountains confine them on the right and left, till, in their progress, they advance to the foot of some mountains where the country is more flat and open; they then expand, and become again invisible. But they are soon pushed against another ridge of mountains by fresh clouds coming up behind them; and in this manner they proceed till they arrive with vast impetuosity at the top of the highest mountains of the Cape, which are those of the

* Tom. i. p. 224.

Wind or of the Table, where they are met by a wind blowing in the very opposite direction. Here a dreadful conflict ensues. The vapours are pressed both before and behind, which produce terrible whirlwinds, either on the mountains of the Table, or in the valleys. When the north-west wind yields, that of the south-east increases, and continues to blow with more or less violence for six months. When the Ox's Eye is thick, the force of the south-east wind augments, because the vapours amassed behind the mountains continually press forward; for the same reason, this wind diminishes when the Ox's Eye is thin; and it entirely ceases when the Ox's Eye vanishes, because no vapours arrive from the east.

" The circumstances attending this phænomenon lead to the following hypotheses:

" 1. Behind the mountain of the Table, a train of thin white vapour is observed, which commences on the eastern declivity of this mountain, ends in a sharp point at the sea, and occupies, in its extent, the whole mountains of Stone. I have often contemplated this train, and imagined it to originate from the rapid motion of the vapour above described, from the mountains of Stone to that of the Table.

" 2. The passage of these vapours must be extremely embarrassed by the contrary shocks received not only from the mountains, but from the south and east winds, which prevail in the neighbourhood of the Cape. I have already mentioned the two mountains situated

on the points of False Bay, the one called the Hanging Lip, the other the Norvege. When the particles or vapours, which I have conjectured, are pushed against these mountains by the east winds, they are repelled by the south winds, and driven against the neighbouring mountains, where they are detained for some time, and appear like clouds, as they often do upon the mountains of False Bay, and even beyond them. These clouds are frequently very thick above the land in the possession of the Dutch, upon the mountains of Stellenbosck, of Drakenstein, and of Stone, but especially upon the mountains of the Table and of the Devil.

"Lastly, the constant appearance of small black clouds upon the Lion's Head two or three days before the south-east wind blows, confirms me in my conjecture; for these clouds, in my opinion, are composed of the particles or vapour mentioned above. If the north-west wind prevails when these particles arrive, their course is stopped, but they are never driven to any great distance till the south-east wind commences."

The navigators who first approached the Cape of Good Hope, were ignorant of the effects of these clouds, which seemed to arise slowly and without any agitation in the air, but which, in a moment, excite the most furious tempests, and precipitate the largest vessels to the bottom of the ocean. In the country of Natal, a cloud, similar to the Ox's Eye at the Cape, produces the same direful effects. These species of tempests

are frequent in the Atlantic, especially in the neighbourhood of the equator. Near the coast of Guinea, three or four of these storms sometimes happen in a day, which are likewise occasioned and announced by small black clouds, while the rest of the sky is generally serene, and the sea perfectly calm. It is principally in April, May, and June, that these furious storms arise along the coast of Guinea, because no regular winds blow there at that season. On the coast of Loango, the stormy season is in the months of January, February, March, and April. At Cape Gardafu, on the other side of Africa, they have storms of this kind in May, and the clouds which produce them are generally in the north, like those of the Cape of Good Hope.

All these storms originate from winds which issue from a cloud; and their direction is from north to south, or from north-east to south-west, &c. But there are tempests of another kind, called whirlwinds, which are still more violent, and in which the wind seems to blow from every quarter at once. Their motion is circular, and nothing can resist their fury. They are generally preceded by a dead calm; but, in an instant, the waves are elevated to the clouds by the fury of the winds. Some parts of the sea cannot be approached; because they are perpetually infested either with calms or whirlwinds. These places have been called *calms* and *tornados* by the Spaniards. The most considerable of them are near Guinea, about the second or

third degree of north latitude. They extend about 300 or 350 leagues in length, and nearly as much in breadth, which includes a space of more than 100,000 square leagues. Calms and storms are so constant on the coast of Guinea, that there are instances of vessels having been retained three months without being able to sail.

When contrary winds arrive at the same time in the same place, they produce whirlwinds, by the opposite motion of the air, in the same manner as whirlpools are produced in the sea by contrary currents. But when these opposite winds are counterbalanced by their distant action upon each other, they then revolve in a great circle and produce a perfect calm, which it is impossible for vessels to navigate. These places are all marked in the globes of Mr. Senex. I am inclined to think, that the contrariety of winds alone, if not assisted by the direction of the coast, and the particular structure of the bottom of the sea in these places, could not produce this effect. I imagine that the currents, which are in effect occasioned by the winds, but assume their direction from the figure of the coasts and the inequalities at the bottom, terminate in these places; and that their opposite motions, in a plain surrounded with a chain of mountains, give rise to the tornados in question.

Whirlpools seem to be nothing else but circular motions of the waters occasioned by the action of two or more opposite currents. The Euripus, so famed by the death of Aristotle, al-

ternately absorbs and rejects the water seven times every twenty-four hours. This whirlpool is near the coast of Greece. Charybdis, which lies near the straits of Sicily, rejects and absorbs the water thrice in twenty-four hours. We are uncertain as to the number of alternate motions in other whirlpools. Dr. Placentia informs us, that the motions of the Euripus are irregular for eighteen or nineteen days every month, and regular during the other eleven; and that it seldom swells above one, or at most two feet. He farther informs us, that authors are not agreed as to the tides in the Euripus; that some say it is twice, others seven times, some eleven, others twelve or fourteen times in twenty-four hours; but that Loirius, who examined it attentively, found that the tides rose regularly every six hours, and that their motion was sufficient to turn a mill wheel.

The largest known whirlpool is in the sea of Norway, the circumference of which exceeds twenty leagues. It absorbs, for six hours, water, whales, ships, and any thing that approaches it, and the next six hours are employed in throwing them up again.

To account for these whirlpools, it is unnecessary to have recourse to an abyss, or to pits in the bottom of the sea, which are perpetually swallowing the waters. It is well known, that, when water runs in two directions, the combination of these motions produces a whirling, and exhibits the appearance of a void space in the middle. In the same manner whirlpools in the

sea are occasioned by two or more contrary currents, and as the tides are the principal cause of currents, and, of course, they run for six hours in contrary directions, it is not surprising, that the whirlpools, which are produced by them, should alternately reject and absorb every thing within their reach during the same portion of time.

Whirlpools, then, are occasioned by contrary currents, and whirlwinds by the conflict of contrary winds. These whirlwinds are common in the Chinese and Japanese seas, near the Antilles, and in many other places of the ocean, particularly in the neighbourhood of prominent coasts. But they are still more frequent upon land; and their effects are sometimes prodigious. "I have seen," says Bellarmin *, "an enormous ditch scooped out by the wind, transported in the air, and dropped upon a village, which was for ever buried under this load of earth." A detail of the effects of several hurricanes may be seen in the History of the French Academy, and in the Philosophical Transactions, which would appear altogether inconceivable, if they were not attested by intelligent and credible spectators.

The same observation may be made with regard to water spouts, which the mariner never beholds without terror and amazement. They are common on certain coasts of the Mediterranean, especially when the weather is cloudy, and the wind blows from several quarters at the

* De Ascensu Mentis in Deum.

same time. They are more frequent near the coasts of Laodicea, of Grecgo, and of Carmel, than in any other part of the Mediterranean. Most of them are large cylinders of water which fall from the clouds, though at a distance the water appears to rise up from the sea to the clouds *.

But there are two species of water spouts; the first is that we have just mentioned, and is nothing but a thick cloud compressed, and surrounded by opposite winds blowing from different quarters at the same time, which make it assume a cylindric figure, and fall down by its own gravity. The quantity of water is so immense, and the rapidity of the fall so great, that if, unfortunately, one of these spouts break upon a ship, it is dashed to pieces, and sinks in an instant. It is alleged, and with probability, that water spouts may be broken and dissipated by the commotion excited in the air by the firing of cannons, which corresponds with the dissipation of thunder clouds by the ringing of bells.

The other species of water spout is called a typhon, and is very frequent in the Chinese Sea. The typhon descends not from the clouds, nor is it produced by the action of opposite winds. On the contrary, it rises from the water to the heavens with amazing rapidity. Whirlwinds often run along considerable tracts, bearing down houses, trees, and every obstacle that they meet with. But typhons remain always in the

* See Shaw's Travels.

same places, and can be owing to nothing but subterraneous fires; for the sea is then in the greatest agitation, and the air is so impregnated with sulphureous exhalations, that the sky appears to be covered with a copper-coloured crust, although there be no clouds, and the sun or the stars appear through the vapour. It is to these subterranean fires that we must ascribe the warmth of the Chinese Sea in winter, where these typhons are very frequent *.

Thevenot, in his voyage to the east, gives the following account of water spouts: "We saw water spouts in the Persic Gulf, between the islands of Quesomo, Lareca, and Ormutz. Few have had the opportunity of observing, and fewer still have paid the attention to water spouts, that I have done. I shall describe them with perspicuity and simplicity, in order to render my account the more intelligible.

"The first that we saw, was on the north side between us and the island of Quesomo, about a gun-shot from our ship. In this place we saw the water begin to boil, and to be raised about a foot above the surface: it was whitish, and the top of it appeared like black smoke: it made a kind of whispering noise, like a torrent rushing down with violence into a deep valley. This noise was mingled with another, that resembled the hissing of serpents. A little afterwards, we saw an obscure canal or pipe, which resembled smoke rising to the clouds, and revolved with

* See Acta Erud. Lips. Supplem. tom. i. p. 405.

considerable velocity: this pipe was about the size of a man's finger; and the same noise continued. It then vanished, having continued in all about a quarter of an hour. We then perceived another on the south, which began in the same manner as the former: immediately a third sprung up to the west, and then a fourth likewise to the west; the most distant from us not exceeding a musket shot. Each of them appeared like heaps of smoking straw, and were accompanied with the same noise as the first. We next perceived three pipes, or canals, extending from the water to the clouds, where each of them terminated like the mouth of a funnel or trumpet, or like the paps of an animal drawn perpendicularly downward by a weight. These pipes were of a dark white colour, which I imagined to be owing to the water they contained; for the pipes appeared to be formed before they were filled with the water, and they disappeared when they were empty; in the same manner as a cylinder of clear glass, when held up in the light at a distance from the eye, is not visible, unless it be filled with some coloured liquor. These pipes were not straight, but bent in some places: they were not even perpendicular; on the contrary, from the clouds into which they were ingrafted, to the places from which they extracted the water, they were very much inclined. And, what is singular, the cloud to which the second of the three was attached, having been pushed forward by the wind, the pipe followed it without breaking, or quitting

its station in the water; and, passing behind the pipe of the first, they remained for some time in the form of a St. Andrew's cross. At first, none of the three exceeded an inch in thickness, except where they joined the cloud: but the one that appeared first, swelled afterwards considerably. The other two continued not longer than the one we had seen to the north. The second, on the south, lasted about a quarter of an hour; but the first, on the same side of the vessel, continued longer, and gave us some uneasiness. Concerning it, therefore, we have still farther to remark, that, although it originally was not larger than a man's finger, it gradually swelled to the size of an arm, then to that of a leg, and, lastly, to that of the trunk of a tree, as large as a man could encompass with both his arms. We saw the water rising distinctly through this transparent body, which was of a serpentine form; and it sometimes diminished in thickness both above and below. It now exactly resembled a soft tube filled with water, and pressed with the fingers, either above to make the fluid descend, or below to make it ascend; and I was satisfied that these variations were occasioned by the wind, which, when it pressed the canal above, caused the water to descend, and, when the pressure was lower down, made the water ascend. After this, it diminished to the size of a man's arm; then it swelled to the size of a thigh; then became exceedingly small; lastly, I perceived that the water elevated from the surface began to sink, and the end of the canal separated from it; when a

variation of the light removed it from my view. I still, however, continued to look for it, because I had remarked, that the canal of the second spout appeared to break in the middle, and to reunite a little afterwards, one half of it having been concealed by the light; but this last never more appeared.

"These spouts are exceedingly dangerous at sea; for, when they fall upon a vessel, they mingle so with the sails, that they sometimes raise the vessel up, and let it fall back again with such violence as to sink it. But, although they should not raise the ship, they tear the sails, or let the whole water they contain fall upon the vessel, which precipitates it to the bottom. It is not improbable, that many vessels, of which we never have any accounts, perish by such accidents, for there are few examples of our ever learning with certainty of ships being lost in this manner."

The above account of water spouts seems to have proceeded from several optical illusions. But I have related the facts *verbatim*, that they may either be confirmed, or at least compared, with those of other navigators. M. Gentil, in his voyage round the world, describes water spouts in the following manner: "At eleven o'clock, before noon, the sky being cloudy, we saw around our ship, at the distance of about a quarter of a league, six water spouts, which began with a noise, like that of water running below ground, and gradually increased till it resembled the hissing noise occasioned by a high wind among the ropes of a ship. We first perceived that the sea

began to boil; and its surface rose about a foot and a half; the top of this elevated part was covered with a thick fog, or rather smoke, which formed itself into a canal, and mounted to the clouds. These canals bended according as the wind carried the clouds to which they were attached. Notwithstanding the motion communicated to the clouds by the wind, the canals not only adhered to them, but seemed to stretch out, or contract, in proportion as the clouds rose higher, or sunk down in the atmosphere.

"These appearances gave us much uneasiness; and our sailors, instead of encouraging each other, increased their fears by dreadful stories. If these spouts, said they, fall upon the ship, they will lift her up, and then plunge her to the bottom. Others maintained, with a decisive tone, that they would not lift the vessel, but that, being full of water, if the ship went forward, she would break their communication with the sea, and that the great body of water, by falling perpendicularly on the vessel, would break her in pieces.

"To prevent this misfortune, they lowered the sails, and charged the cannon. It is a general opinion among sailors, that the firing of cannon, by agitating the air, bursts and disperses water spouts. But we were not under the necessity of having recourse to this expedient; for, after coursing round the ship for about ten minutes, some being about a quarter of a league from us, and others nearer, the canals became gradually narrower, detached themselves from

the surface of the sea, and then entirely vanished *."

From the description of these two voyagers it appears, that water spouts are produced, at least in part, by the action of fire or smoke, which rises with violence from the bottom of the sea; and that they are very different from those which are occasioned by opposite winds.: "The water spouts," says Mr. Shaw †, "which I had the opportunity of seeing, seemed to be so many cylinders of water falling down from the clouds; though by the reflection, it may be of those decending columns, or from the actual dropping of the water contained in them, they would sometimes appear, especially at a distance, to be sucked up from the sea. Nothing more, perhaps, is required to explain this phænomenon, than that the clouds should be first of all crowded together, and then, that contrary winds, pressing violently upon them, should occasion them to condense, and fall in this cylindrical manner."

Many facts remain still to be known before these phœnomena can be properly explained. To me it appears, that, if there be, in particular places, at the bottom of the sea, a mixture of sulphur, bitumen, and mineral substances, these may occasionally be inflamed, which will produce, like the explosion of gunpowder, a great quantity of air; and that this air newly generated, and rarefied to a prodigious degree, mounts with rapidity, and may elevate the water from

* Tom. i. p. 191. † Shaw's Travels, p. 334.

the sea to the clouds. In the same manner, if a perpendicular current of air be produced by the explosion of sulphureous matter in a cloud, the whole of its water may follow this current, and give rise to a water spout from the clouds to the sea. But, it must be acknowledged, that this account of the last species of spout is not more satisfactory than that which we have given of those produced by contrary winds; for it may be asked, why those spouts, which originate from the clouds, are not as common on land as upon the sea?

The historian of the Academy for the year 1727, mentions a land water spout that appeared at Capestan near Beziers. It descended from a cloud, like a black pillar, which gradually diminished, and ended in a point upon the surface of the earth. It followed the direction of the wind, which was westerly; it was attended with a thick smoke, and made a noise like the sea when greatly agitated. It tore up trees by the roots, and marked its way on the earth by a large tract in which three carriages might have passed each other. Another pillar of the same kind appeared, but it soon joined the first; and, when the whole was dissipated, there fell a great quantity of hail.

This species of water spout appears to be different from the other two. It is not said to have contained water; and it seems, both from what I have mentioned, and by M. Andoque's explication of it to the Academy, to have been only a hurricane rendered visible by the dust and con-

densed vapour which it contained. The same historian, for the year 1741, mentions a water spout which was seen upon the lake of Geneva. It was of a cylindrical figure, the upper part of which ended in a black cloud, and the under part of it was narrow, and terminated near the surface of the water. This meteor continued only a few minutes; and, at the moment of its dissipation, a thick vapour ascended from the place where it first appeared; the water of the lake boiled, and seemed to make an effort to rise into the air, which was very calm the whole time; neither was this spout followed either by wind or rain. "After all our knowledge of water spouts," says the historian, "does not this prove that they are not produced by the conflict of opposite winds alone, but that they almost always originate from volcanos or subterraneous vapours, which are known to exist at the bottom of the sea, as well as upon land? Whirlwinds and hurricanes, therefore, which are generally believed to be the cause of these appearances, may be only an effect or an accidental consequence of them."

M. de la Nux, whom I have often quoted, and who lived forty years in the isle of Bourbon, has had an opportunity of seeing a great number of water spouts, and he has communicated to me his observations, of which the following is an abridgement:

The water spouts observed by M. de la Nux were formed, 1. In calm days, and in those intervals when the wind passes from the south to

the north; though he saw one, which was formed previous to this passage of the wind from one quarter to another, and even in the current of a north wind, *i. e.* a pretty long time before this wind had ceased: the cloud from which this water spout depended, and to which it was attached, was still violently driven to the south. The sun, at the same time, was seen behind the cloud to the south. It happened on the 6th day of January, about eleven o'clock before noon.

2. These water spouts are formed during the day in detached clouds, apparently very thick, much longer than broad, and well defined below in the direction of the horizon: the under part of these clouds is always very black.

3. All these water spouts at first appear under the form of inverted cones, whose bases are more or less extensive.

4. Several of those water spouts that appear under the figure of inverted cones are sometimes attached to the same cloud; some are never entirely completed; some are dissipated at a small distance from the cloud; and others descend apparently very near to the surface of the sea, under the form of a long flat cone, which is narrow and pointed at the bottom. In the centre of this cone, and through its whole length, there is a whitish transparent canal, about one third of the diameter of the cone, the two sides of which were very black, especially on their first appearance.

These water spouts were observed from a point in the isle of Bourbon elevated 150 fathoms

above the level of the sea, and they were generally three, four, or five leagues from the place of observation, which was the house of M. de la Nux.

The following is a more particular description of these water spouts:

When the end of the shaft, or top of the cone, which is then very sharp pointed, has descended about a fourth of the distance of the cloud from the sea, we begin to perceive on its surface, which is commonly calm and of a transparent whiteness, a small black circle, which is produced by the agitation and whirling of the water: in proportion as the point of this shaft descends, the water boils; this boiling increases in proportion as the point approaches toward the surface, and the water of the sea rises in successive whirlings to a greater or smaller height, which, in the largest water spouts, is about twenty feet. The end of the shaft is always above this whirling, the size of which is proportioned to that of the water spout, which puts it in motion. The end of the shaft seems not to touch the surface of the sea, otherwise than by joining itself to the boiling or whirling which rises to meet it.

We sometimes see larger and smaller cones of water spouts proceeding from the same cloud; some of them have the appearance of threads, and others are much larger. We often see ten or a dozen of small but complete water spouts issuing from the same cloud, most of which are dissipated near their exit, and visibly ascend to

the cloud. In this last case, the shaft suddenly swells as far as the inferior, extremity, and appears like a cylinder suspended from the cloud, torn in pieces below, and of a small extent.

The water spouts with broad bases gradually enlarge through their whole extent, and likewise in the under end, which seems to recede from the sea and to approach the cloud. The agitation and whirling they produce in the water gradually diminishes, and the under part of the shaft soon enlarges, and assumes nearly a cylindrical form. It is in this state that the two sides of the canal widen; and we then see the water rushing with rapidity, and in a spiral form, into the cloud. Lastly, the appearance of the water spout terminates by the successive shortening of this species of cylinder.

The largest water spouts remain longest without dissipating; and some of them continue more than half an hour.

A torrent of rain generally rushes out of the same part of the cloud from which the water spouts issue, and some of them not unfrequently still adhere to the cloud; these torrents of rain often conceal water spouts before they are dissipated. "I perceived distinctly," M. de la Nux remarks, "on the 26th of October, 1755, a water spout in the middle of one of these torrents, which became so great, that it was soon concealed from my view."

The wind, or the agitation of the air below the cloud, breaks neither the large nor the small

water spouts; for this impulsion only declines them from the perpendicular. The smallest kinds form very remarkable curves, and even sinuosities. The extremity which terminates in the sea is often far removed from the direction of the other which is attached to the cloud.

We never see new water spouts formed after rain has fallen from the clouds which produced them.

"On the 14th day of June, 1756, about four o'clock afternoon, I was," says M. de la Nux, "on the margin of the sea, and above its level twenty or twenty-five feet. I saw twelve or fourteen water spouts issue from the same cloud. Three of them only were considerable, and particularly the last. The canal in the middle of the cylinder was so transparent, that, as the sun shone, I saw the clouds behind it. The cloud which produced so many water spouts extended nearly from south-east to south-west; and the large water spout under consideration appeared in the south south-west from my station. The sun was very low; for the days were then about the shortest. I saw no rain proceed from the cloud: its height seemed to be from five to six hundred fathoms."

The more the sky is obscured with clouds, water spouts, and the phænomena which accompany them, are the more easily observed.

M. de la Nux thinks, and perhaps with reason, that water spouts are nothing but viscous portions of a cloud driven off by different whirl-

winds, *i. e.* by the whirlings of the superior air sinking into the mass of vapours of which the whole cloud is composed.

What seems to prove that these water spouts are composed of viscous parts, is the tenaciousness of their cohesion; for they make inflections and curvatures in every direction, without breaking: if the matter of water spouts was not viscous, how can we conceive that they should, without breaking, bend and obey the motion of the winds? If all the parts did not firmly adhere, the wind would dissipate them, or, at least, make them change their form. But, as the form both of the large and small water spouts is uniformly the same, this is almost a certain indication of the viscous tenacity of the matter of which they are composed.

Thus the basis of the matter of water spouts is a viscous substance contained in the clouds, and every water spout is formed by a whirlwind of air pressing through the mass of vapours, and, by blowing up the inferior part of the cloud, pierces it, and descends with its covering of viscous matter. And, as complete water spouts descend from the cloud to the surface of the sea, the water must boil and whirl at the place to which the end of the water spout is directed; because the air blows from the extremity of the water spout like the tube of a pair of bellows. The effects of this blowing upon the sea will augment, in proportion as the cylinder approaches the surface of the water; and, when the orifice of the tube enlarges, a greater quantity of air is per-

mitted to escape, and the agitation of the water is, of course, increased.

It has been imagined, that water spouts carried off and contained great quantities of sea water: the rains, or rather the spray, which often fall in the neighbourhood of water spouts, have strengthened this prejudice. The canal in the middle of every species of water spout is always transparent, on whatever side it is viewed. If the water of the sea seems to rise, it is not in this canal, but only on its sides. Almost every water spout suffers inflections, and often in opposite directions, in the form of an *S*, the one end of which is in the cloud, and the other in the sea. Hence these water spouts, of which we have been treating, cannot contain water either to be poured into the sea, or raised to the cloud. Of course, they can be attended with no danger, except what proceeds from the impetuosity of the air which escapes from their inferior orifice; for we are assured by every person who has had an opportunity of observing these water spouts, that they are solely composed of air confined in a viscous cloud, and determined by its whirling to the surface of the sea.

M. de la Nux has seen water spouts around the isle of Bourbon in the months of January, May, June, and October, *i. e.* in all seasons of the year. He has seen them in calm weather, and during the highest winds. These phænomena, however, may be said to be rare, and seldom appear but upon the sea; because the

viscosity of the clouds can only proceed from the bituminous and greasy particles raised, by the heat of the sun and the winds, from the waters of the sea, and collected in the clouds near its surface. It is for this reason that water spouts seldom appear on land, where there is not, as on the surface of the sea, a sufficient quantity of bituminous and oily particles to be exhaled by the action of the sun. They are sometimes, however, observed on land, and even at great distances from the sea; this effect may be produced, when viscous clouds have been rapidly driven by a violent wind from the sea toward the land. M. Grignon, in the month of June, 1768, saw a well-formed water spout in Lorrain, near Vauvillier, among the hills, which are a continuation of the Vosges. It was about fifty fathoms high. Its form was that of a column, and it communicated with a large thick cloud. It was impelled by one or several winds, which made the water spout turn rapidly; and it produced lightning and thunder. This water spout continued seven or eight minutes only, and broke upon the base of the hill, which is from five to six hundred feet high *.

Water spouts have been mentioned by several voyagers; but no man has examined them with such accuracy as M. de la Nux. For example, these voyagers tell us, that, when water spouts are forming, a black smoke rises on the suface of

* Note communicated by M. Grignon to M. de Buffon, Aug. 6, 1777.

the sea: this appearance, we are certain, is deceitful, and proceeds solely from the situation of the observer. If he is placed on a situation so elevated, that the distance of the whirling excited in the water by the spout exceeds not his sensible horizon, he will see nothing but the water rising and falling back in rains, without any mixture of smoke. This fact is apparent when the sun shines on the place where the phænomenon happens.

These water spouts have nothing in common with those agitations and smoke sometimes produced by submarine fires, and of which we have formerly treated. Water spouts neither contain nor excite any smoke. They are every where rare: they are most frequent in the seas of warm climates, and where, at the same time, calms are common, and the winds are most inconstant. They are likewise more frequent, perhaps, near islands and coasts than in the open sea.

END OF VOL. I.

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